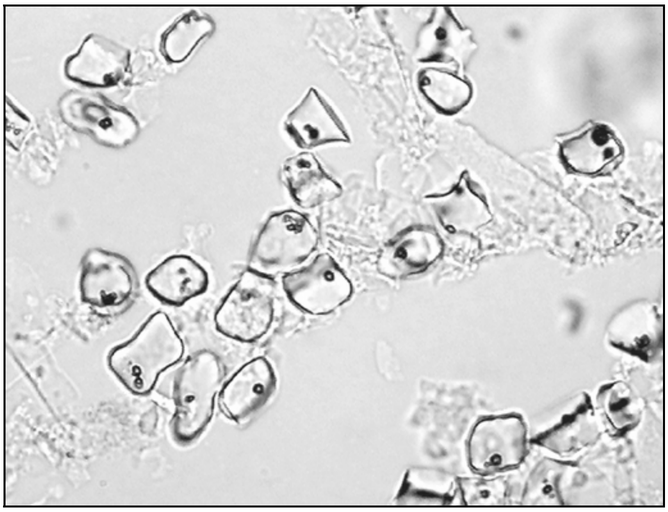
ISSN 0375 8192

June 2004

Antarctic Data Series No 29

AN ANNOTATED BIBLIOGRAPHY OF PHYTOLITH ANALYSIS AND ATLAS OF SELECTED NEW ZEALAND SUBANTARCTIC AND SUBALPINE PHYTOLITHS

V.C. Thorn



ANTARCTIC RESEARCH CENTRE
in association with the

SCHOOL OF EARTH SCIENCES
Te Kura Tātai Aro Whenua

VICTORIA UNIVERSITY OF WELLINGTON
Te Whare Wananga o te Upoko o te Ika a Maui

Antarctic Data Series No. 29
A Publication of the Antarctic Research Centre:
Victoria University of Wellington
PO Box 600, Wellington, New Zealand

This publication is available in pdf format at our ftp site.
ftp://ftp.geo.vuw.ac.nz/ARC/

Contents

Summary

Phytoliths are plant microfossils composed of amorphous, biogenic opal silica that is deposited between and within the cells of many living plants. When released on the death of the plant, phytoliths form a near *in situ* record in the soil beneath of the former vegetation at that site. The value of studying dispersed phytolith assemblages, either from the soil or further down the particle transport pathway in, for example, fluvial or offshore sediments, is similar to that of terrestrial palynomorphs. Relevant modern analogues allow the phytolith record to provide complementary or even supplementary information towards palaeovegetation and palaeoclimate reconstructions from pollen and spores.

Phytoliths have been studied from localities all over the world, however, only recently has attention turned to phytolith production and preservation in the high southern latitudes (Carter 1998, 1999; Thorn 2001, 2004). Research on Antarctic margin sediments, towards an understanding of the Cenozoic history of the East Antarctic Ice Sheet, has previously involved numerous terrestrial palynomorph studies, which have led to interpretations about the terrestrial palaeoclimatic conditions during ice sheet development (Askin 1997; Askin 2000; Askin and Raine 2000; Raine and Askin 2001; MacPhail and Truswell 2004). A recent study (undertaken during the tenure of a New Zealand Foundation for Research, Science and Technology Post-Doctoral Fellowship hosted by the Antarctic Research Centre) has searched for phytoliths in many of the same sediments with a view to providing additional information about Antarctic margin vegetation during ice sheet development. In addition, due to the necessity for modern reference material for the interpretation of fossil phytoliths, a study of phytolith production in several modern New Zealand subantarctic and subalpine plant species provides the basis of an analogue collection for future high latitude phytolith studies.

This issue consists of two parts. The first part presents an annotated bibliography of key phytolith reference material with particular attention to palaeoecological and palaeoclimatological studies. The second part presents the initial data from the modern analogue investigation in atlas form, plus laboratory techniques for extracting phytoliths from plants, soils and sediments.

Summary References

Askin, R., A., 2000. Spores and pollen from the McMurdo Sound Erratics, East Antarctica. In: J.D. Stilwell and R.M. Feldmann (Editors), Paleobiology and Paleoenvironments of Eocene rocks, McMurdo Sound, Antarctica. Antarctic Research Series. American Geophysical Union, Washington, D.C., pp. 161-181.

Askin, R.A., 1997. Eocene - ?Earliest Oligocene terrestrial palynology of Seymour Island, Antarctica. In: C.A. Ricci (Editor), The Antarctic Region: Geological Evolution and Processes, pp. 993-996.

Askin, R.A. and Raine, J.I., 2000. Oligocene and Early Miocene terrestrial palynology of the Cape Roberts drillhole CRP-2/2A, Victoria Land Basin, Antarctica. Terra Antartica, 7(4): 493-501.

Carter, J.A., 1998. Phytolith Report of Mount Feather Cores. In: G.S. Wilson and J.A. Barron (Editors), Mount Feather Sirius Group Core Workshop. Byrd Polar Research Center, Columbus, Ohio, pp. 69-74.

Carter, J.A., 1999. Late Devonian, Permian and Triassic phytoliths from Antarctica. Micropaleontology, 45(1): 56-61.

MacPhail, M.K. and Truswell, E., M., 2004. Palynology of Neogene slope and rise deposits from ODP Sites 1165 and 1167, East Antarctica. In: A.K. Cooper, P.E. O'Brien and C. Richter (Editors), Proceedings of the Ocean Drilling Program Scientific Results. Ocean Drilling Program, College Station, TX.

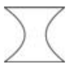
Raine, J.I. and Askin, R., A., 2001. Vegetation history and climate from the Early Oligocene to Early Miocene, Cape Roberts, Ross Sea region, Antarctica. In: F. Florindo and A.K. Cooper (Editors), The geologic record of the Antarctic ice sheet from drilling, coring and seismic studies. Quaderni di Geofisica. Istituto Nazionale di Geofisica e Vulcanologia, Erice, Italy, pp. 157.

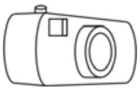
Thorn, V.C., 2001. Oligocene and early Miocene phytoliths from CRP-2/2A & CRP-3, Victoria Land Basin, Antarctica. Terra Antartica, 8(4): 407-422.

Thorn, V.C., 2004. Data Report: Phytoliths in drill core sediments from Sites 1165 and 1166, Leg 188, Prydz Bay, East Antarctica. Proceedings of the Ocean Drilling Program Scientific Results, 188.

Part 1: Annotated Bibliography

Key to Symbols

 Taxonomy / classification

 Photographic phytolith images

 Methodology

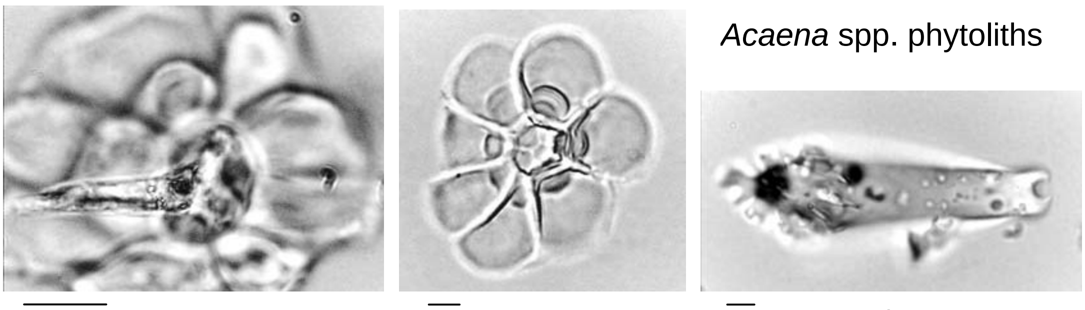
 Bibliography

 New Zealand

 Australia

 Marine core study

 Sea ice core study



Acaena spp. phytoliths

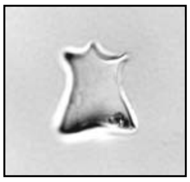
Scale bars = 10 μm

Introduction

Phytoliths are plant microfossils composed of amorphous, biogenic opal silica that are deposited between and within the cells of many living plants. This bibliography aims to provide the reader with the means to begin an investigation of the field of phytolith analysis with particular reference to the application of this technique to palaeoecology and palaeoclimatogy using the fossil record.

The references presented have been collated during post-doctoral research funded by the New Zealand Foundation for Research, Science and Technology and hosted by VicLink Limited and the Antarctic Research Centre at Victoria University of Wellington. The bibliography contains mention of worldwide phytolith studies relevant to palaeoecology with particular attention to the Australasian and Antarctic regions.

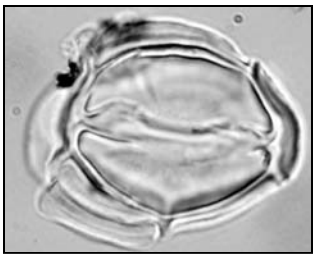
Different resource types are organised into separate sections, then sorted by first author and year of publication (most recent first). Each reference is annotated with a brief description of the content and symbols highlighting specific themes (refer to the key on the previous page.



10 μm

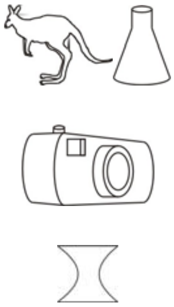
It should be understood that this bibliography is not exhaustive, for example, entirely non-English language references have not been reviewed. For these and additional references the reader is referred to other published bibliographies listed and indicated by an open book symbol. Conference proceedings volumes contain extensive reference lists and commonly include useful background information such as reviews of the status of phytolith research at the time of publication, review articles on different topics within phytolith analysis, historical overviews and information on new techniques.

This bibliography also includes selected electronic resources that take advantage of the ease of rapid communication of information, especially images, and the low cost of publishing on the worldwide web. This valuable new source of phytolith reference material includes on-line databases, software and CD-ROMs. The web-sites listed contain significant content about phytoliths, either as background information, images and/or descriptions or presentations of research projects. The communication of images and accompanying descriptions of modern analogues is of fundamental importance to the worldwide application of phytoliths to palaeoecology. Many additional sites currently exist containing small amounts of information about phytoliths or advertising phytolith processing services that linked from the sites listed or can be found by entering relevant keywords into internet search engines. The URLs or email list owners will inevitably change as the author/owner moves location, however, the pages can often be found again with a relevant keyword search.



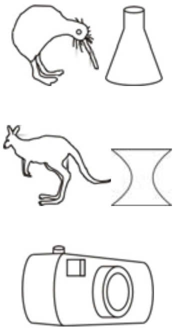
10 μm

Books & Conference Proceedings



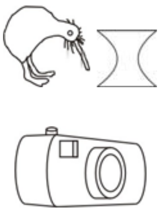
Bowdery, D., 1998. Phytolith Analysis applied to Pleistocene-Holocene Archaeological Sites in the Australian Arid Zone. John Erica Hedges, Hadrian Books, Oxford, England.

This book presents an archaeological phytolith study, that includes a comprehensive introduction to the field of phytolith analysis (Chapter Two) and describes the methods and classification techniques employed in detail. SEM images organised into 13 photographic plates are included.



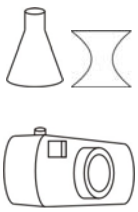
Hart, D. & Wallis, L., 2003. Phytolith and Starch Research in the Australian-Pacific-Asian Regions: the State of the Art. Conference: August 2001, The State of the Art in Phytolith and Starch Research in the Australian-Pacific-Asian regions, Australian National University. Pandanus, Canberra, Australia.

This issue of the Terra Australis series brings together many of the papers and posters presented at a conference on phytolith and starch research in the region held at The Australian National University in Canberra in August 2001.



Kondo, R., Childs, C. & Atkinson, I., 1994. Opal Phytoliths of New Zealand. Manaaki Whenua Press, Lincoln.

This book is a key reference for New Zealand phytoliths including forms extracted from plants (several indigenous grasses, ferns and trees), soils (both modern and buried), sediments (tephras and Ross Sea CIROS marine cores) and moa faeces. The book provides descriptions and SEM plates.



Meunier, J., Dominique & Colin, F. (Eds.), 2001. Phytoliths: Applications in Earth Sciences and Human History. A.A. Balkema Publishers, Lisse.

This book presents the most recent advances in phytolith research and includes 30 papers under the following topics: Phytoliths in Paleoclimatology and palaeoecology; Phytoliths, diet and health; Archaeological structures, ancient agriculture and paleoethnobotany; Methodology, taxonomy and taphonomy; Soil-plant interactions. A notable contribution is a suggested universal phytolith key (refer to Bowdery et al, 2001 in 'Book Sections' section). Figures and tables are included.

Pearsall, D., 2000. Paleoethnobotany - a Handbook of Procedures. Academic Press, San Diego.

This textbook includes a chapter on phytolith analysis covering many different aspects. The sections presented are: Nature and occurrence of phytoliths; Phytoliths and archaeology: a brief history; Field sampling; Laboratory analysis; Presenting and interpreting results; Issues and directions in phytolith analysis. The phytolith chapter includes many light microscopy phytolith images.

Pearsall, D. & Piperno, D. (Eds.), 1993. Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology. MASCA Research Papers in Science and Archaeology, 10. MASCA, The University Museum of Archaeology and Anthropology, University of Pennsylvania, Philadelphia.

This volume includes contributions under the headings: New techniques and approaches; Palaeoecological reconstruction and Subsistence and agriculture. It also includes comment on the status of phytolith analysis and future prospects. Notable sections include a discussion of AMS radiocarbon, thermoluminescence and isotopic dating of phytoliths and the application of quantatitive methods and statistical analyses.

Pinilla, A., Juan-Tresserras, J. & Machado, J., 1997. The State-of-the-Art of Phytoliths in Soils and Plants. First European Meeting on Phytolith Research, 4. Centro de Ciencias Medioambientales, CSIC, Madrid.

This proceedings volume of the first European meeting on phytolith research covers topics in soils, plants, archaeology and palaeoecology. Notable contributions in the latter category include oxygen isotope geochemistry and preliminary morphology classification using computerised image analysis and pattern recognition.

Piperno, D.R., 1988. Phytolith Analysis, An Archaeological and Geological Perspective. Academic Press Inc. (London) Ltd., London.

A comprehensive text for phytolith analysis. Chapters: History of phytolith research; The production, deposition, and dissolution of phytoliths; Phytolith morphology, Field techniques and research design; Laboratory techniques; The interpretation of phytolith assemblages: method and theory; The role of phytoliths in archaeological reconstruction; The role of phytoliths in regional palaeoecology. Plates (SEM and light microscopy photographs) and phytolith keys are included for several tropical domesticates.

Rapp, G. Jr & Mulholland, S. (Eds.), 1992. Phytolith Systematics: Emerging Issues. Advances in Archaeological and Museum Science, 1. Plenum Press, New York.

This book provides a summary of the state of phytolith systematics at the time of publishing to address issues including the paucity of data on many important plant groups and the lack of adequate keys and/or comparative collections. Notable chapters include a suggested phytolith classification system, a morphological classification of grass phytoliths and an annotated bibliography. Several figures and tables are included.

Runge, F., 2000. Opal-phytolithe in den Tropen Afrikas. Books on Demand, Norderstedt.

An atlas and analysis of phytoliths from plants, soils and sediments from tropical Africa. Transmitted light microscope and SEM images are included. In German. Summary and Results sections in English.

Book Sections

Boettinger, J., 1994. Biogenic opal as an indicator of mixing in an Alfisol/Vertisol landscape. In: Ringrose-Voase, A. & Humphreys, G. (Eds.), Soil Micromorphology: Studies in Management and Genesis. Proceedings of the IX International Working Meeting on Soil Micromorphology. Developments in Soil Science. Elsevier, Amsterdam, Townsville, Australia, pp. 17-26.

This article presents a study of the vertical mixing of phytoliths between Alfisol/Vertisol soil layers in Queensland, Australia. Phytoliths were concentrated in the surface of the low-activity Alfisols and occurred throughout the solum of the high shrink-swell Vertisols. It is suggested that the primary reason for this apparent mixing was incorporation of phytoliths into the soil at depth after they had fallen into desiccation cracks.

Bowdery, D., 1999. Taphonomy, phytoliths and the African Dust Plume. In: Mountain, M. (Ed.), Taphonomy: the Analysis of Processes from Phytoliths to Megafauna. Research Papers in Archaeology and Natural history. ANH Publications, ANU, Canberra, pp. 3-8.

This article describes the general lack of phytolith illuviation through Australian sediments and reviews historical and contemporary evidence of long-distance phytolith transport within the African dust plume. Fluctuations in phytolith content within deep sea sediment cores off Africa are suggested to reflect vegetation changes in the source area. Outline illustrations of Poaceae phytoliths are included.

Bowdery, D., Hart, D., Lentfer, C. & Wallis, L., 2001. A Universal Phytolith Key. In: Meunier, J. & Colin, F. (Eds.), Phytoliths: Applications in Earth Sciences and Human History. A.A. Balkema Publishers, Lisse, pp. 267-278.

This article attempts a comprehensive phytolith classification system presenting a key based on eight disarticulated shape categories and highlighting surface ornamentation terminology. It includes SEM photos as illustrations of key descriptors.

Bozarth, S., 1993. Biosilicate assemblages of boreal forests and aspen parklands. In: Pearsall, D. & Piperno, D. (Eds.), Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology. MASCA Research Papers in Science and Archaeology. The University Museum of Archaeology and Anthropology, Philadelphia, pp. 95-105.

This is a palaeoenvironmental study which assesses the applicability of phytolith analysis for the reconstruction of Wisconsinan vegetation in the central Great Plains of the US. Phytoliths were extracted from soils beneath tree stands and the common arboreal and understorey species for reference. It is concluded that boreal forest and aspen stands do produce identifiable associated phytolith or phytolith/diatom assemblages which provide useful analogues for late Quaternary vegetation reconstruction in the region. Light microscopy photos are included.

Bozarth, S.R., 1992. Classification of opal phytoliths formed in selected dicotyledons native to the Great Plains. In: Rapp, G. Jr & Mulholland, S. (Eds.), Phytolith Systematics - Emerging Issues. Advances in Archaeological and Museum Science. Plenum Press, New York, pp. 193-214.

This article presents diagnostic phytoliths from a modern reference collection of 65 herbaceous dicotyledon and 20 woody dicotyledon species native to the central US Great Plains. It describes nine major phytolith types, four of which occur in both herbaceous and woody species and other types appear specific to certain families or genera. Light microscopy photographs are included.

Bukry, D., 1979. Comments on opal phytoliths and stratigraphy of Neogene silicoflagellates and coccoliths at Deep Sea Drilling Project Site 397 off northwest Africa. In: Luyendyk, B. (Ed.), Initial Reports of the Deep Sea Drilling Project. U.S. Government Printing Office, Washington, pp. 977-1009.

This article discusses phytoliths, silicoflagellates and coccoliths from deep sea cores off northwest Africa. Phytoliths occur in low or moderate numbers at some levels in Pliocene and Quaternary core samples. Their association with freshwater diatoms suggests an eolian transport mechanism. Light microscopy images are included.

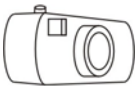
Carter, J., 1998. Phytolith Report of Mount Feather Cores. In: Wilson, G. & Barron, J. (Eds.), Mount Feather Sirius Group Core Workshop. Byrd Polar Research Center, Columbus, Ohio, pp. 69-74.

This article is part of a multidisciplinary study of cores recovered from the Mount Feather Diamicton in the Transantarctic Mountains. Nine phytolith categories are described and illustrated with three modern analogues for comparison (light microscopy images). Tentative natural affinities are presented.

Dumitrica, P., 1973. Phytolitharia. In: Kaneps, A. (Ed.), Initial Reports of the Deep Sea Drilling Project. U.S. Government Printing Office, Washington, pp. 940-943.

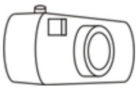
Phytoliths from Mediterranean Deep Sea Drilling Program cores are described and classified into four paragenera. Clear outline drawings are included. It is suggested that phytoliths may be a valuable tool in the future for palaeoecological analysis in combination with pollen analysis.

Kondo, R., Sase, T. & Kato, Y., 1987. Opal phytolith analysis of Andisols with regard to interpretation of paleovegetation. In: Kinloch, D., Shoji, S., Beinroth, S. & Eswaran, H. (Eds.), Proceedings of the Ninth International Soil Classification Workshop, Japan, pp. 520-534.



This article discusses the phytoliths accumulated in humus horizons and their relationship to vegetation change and humus accumulation in Japan. A significant correlation links the amounts of total organic carbon and phytoliths in modern and buried soils. Changes in grassland type back to c. 20 k.y. ago are discussed from the profiles. Two SEM phytolith images are included.

Locker, S. & Martini, E., 1986. Phytoliths from the southwest Pacific, Site 591. In: Kennett, J. (Ed.), Initial Reports of the Deep Sea Drilling Project. US Government Printing Office, Washington, pp. 1079-1084.

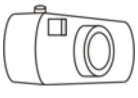


Windblown phytoliths are described from deep sea cores in the southwest Pacific throughout Miocene to early Pleistocene sediments. The phytoliths are sourced from the semi-arid and arid regions of Australia. A peak in abundance during the Pliocene coincides with palaeogeographic and palaeoclimatic trends including the development of arid conditions on the Australian continent. Light microscopy images are included.

Mulholland, S., Lawlor, E. & Rovner, I., 1992. Annotated bibliography of phytolith systematics. In: Rapp, G., Jr & Mulholland, S. (Eds.), Phytolith Systematics - Emerging Issues. Plenum Press, New York, pp. 277-322.

This bibliography (c.450 references, 45 pp.) presents citations referring to phytolith systematics. Annotations include a brief content summary and lists of illustrations and tables.

Mulholland, S. & Rapp, G. Jr., 1992. A morphological classification of grass silica-bodies. In: Rapp, G. Jr. & Mulholland, S. (Eds.), Phytolith Systematics: Emerging Issues. Advances in Archaeological and Museum Science. Plenum Press, New York, pp. 65-90.



This article presents a key for the morphological classification of grass phytoliths, correlated to anatomical origin. Three general geometric shapes are subdivided into eight types based on outline including basic three-dimensional structure. Light microscopy photographs illustrate morphological categories.

Ollendorf, A., 1992. Towards a classification scheme of sedge (Cyperaceae) phytoliths. In: Rapp, G. Jr & Mulholland, S. (Eds.), Phytolith Systematics - Emerging Issues. Plenum Press, New York, pp. 91-111.

A compilation of information on sedge (Cyperaceae) cone phytoliths from widely separated geographic areas is presented in this article with a view to the development of a standard classification scheme for phytoliths from this family. SEM photographs illustrate examples extracted from different species.

Pearsall, D., 1992. Developing a phytolith classification system. In: Rapp, G. Jr & Mulholland, S. (Eds.), Phytolith Systematics - Emerging Issues. Plenum Press, New York, pp. 37-64.

This article presents a phytolith classification scheme under development at the Paleoethnobotany Laboratory of the University of Missouri-Columbia. It uses photo-identification to categorise phytoliths into numbered types on the basis of cellular origin (major categories) and morphology (minor categories). Classification issues are also discussed and light microscopy photographs included.

Piperno, D., Flood, R., Piper, D., Klaus, A. & Peterson, L., 1997. Phytoliths and microscopic charcoal from Leg 155: vegetational and fire history of the Amazon Basin during the last 75 k.y. In: Flood, R. (Ed.), Proceedings of the Ocean Drilling Program Scientific Results, pp. 411-418.

This article reports on phytolith analysis from Amazon Fan sediment cores (Ocean Drilling Program Sites 932 and 933) representing the last 75 k.y.. Phytoliths indicate Pleistocene climate was much cooler than today and the Last Glacial Maximum much drier with frequent grassland fire. There are no phytolith images.

Powers-Jones, A., 1992. Great expectations: a short historical review of European phytolith systematics. In: Rapp, G. Jr & Mulholland, S. (Eds.), Phytolith Systematics - Emerging Issues. Plenum Press, New York, pp. 15-35.

A historical review of the study of phytoliths in Europe from early German observations in the nineteenth century to the time of writing including discussion of the continual updating of phytolith classification.

Powers-Jones, A. & Padmore, J., 1993. The use of quantitative methods and statistical analyses in the study of opal phytoliths. In: Pearsall, D. & Piperno, D. (Eds.), Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology. MASCA Research Papers in Science and Archaeology. The University Museum of Archaeology and Anthropology, Philadelphia, pp. 47-56.

This article provides a useful review of statistical techniques available to the phytolith analyst in order to interpret large data sets. Cluster analysis and correspondance analysis are explained and examples provided.

Twiss, P., 1992. Predicted world distribution of C_3 and C_4 grass phytoliths. In: Rapp, G. Jr. & Mulholland, S. (Eds.), Phytolith Systematics – Emerging Issues. Plenum Press, New York, pp. 113-128.

This article discusses the different morphology of phytoliths produced by C_3 and C_4 grasses and suggests that the ratio between the different types could be used to reconstruct Cenozoic palaeoclimate from dispersed assemblages based on the modern ranges of these grasses.

Journal Articles

Abrantes, F., 2003. A 340,000 year continental climate record from tropical Africa - News from opal phytoliths from the equatorial Atlantic. Earth and Planetary Science Letters, 209(1-2), 165-179.

Tropical African continental climate and vegetation over the last 340 k.y. is investigated from eolian-sourced phytoliths within a deep-sea Atlantic core at site M16772. Total phytolith accumulation rate is dominated by C_4 grasses and their variability confirms the cold stages and interstadials as arid periods in the Sahara and Sahel regions. Major fluctuations in continental aridity and/or wind strength over north Africa appear to reflect global ice volume and the 100 k.y. cycle characteristic of high-latitude climate change.

Almond, P., Moar, N. & Lian, O., 2001. Reinterpretation of the glacial chronology of South Westland New Zealand. New Zealand Journal of Geology and Geophysics, 44(1), 1-15.

Total element, mineral and phytolith analysis has been used to test the correlation of loess/soil stratigraphic units with climatic events. Intense weathering resulted in the limited use of luminescence dating. However, loess stratigraphy is revised for South Westland and is consistent with recent studies in Fiordland suggesting a more complex glacial stratigraphy for the Otiran than is recognised in North Westland.

Baker, G., 1960. Phytoliths in some Australian dusts. Proceedings of the Royal Society of Victoria, 72(1), 21-40.

Phytoliths are described from dust collections undertaken by the Army Department to ascertain how phytoliths affect the wear in vehicles. Many different forms are clearly illustrated in outline drawings.

Baker, G., 1960. Fossil opal-phytoliths. Micropaleontology, 6(1), 79-85.

This article describes the discovery of phytoliths in Tertiary and Quaternary sediments from Victoria, Australia and recognises their potential for palaeoecological analyses. A comment is made that given the right conditions for dehydration, phytoliths would convert to chalcedony or crystalline quartz and therefore lose any resemblance to the original phytolith form.

Barboni, D., Meunier, J., Bonnefille, R. & Alexandre, A., 1999. Phytoliths as paleoenvironmental indicators, West Side Middle Awash Valley, Ethiopia. Palaeogeography, Palaeoclimatology, Palaeoecology, 152(1-2), 87-100.

This article describes a study from arid tropical Ethiopia, which uses surface, soil and sediment phytolith assemblages to successfully reconstruct vegetation during the Holocene and Pleistocene for archaeological applications.

Blecker, S., Yonker, C., Olson, C. & Kelly, E., 1997. Paleopedologic and geomorphic evidence for Holocene climate variation, Shortgrass Steppe, Colorado, USA. Geoderma, 76, 113-130.

Five palaeosols from the Shortgrass Steppe of Colorado were analysed for grain size and phytoliths to characterise distinct periods of climate stablility and instability indicated from radiocarbon dates. Organic carbon and phytolith data suggest early and middle Holocene climate was more favourable for plant productivity, due to moister conditions, than the present.

Blinnikov, M., Busacca, A. & Whitlock, C., 2002. Reconstruction of the late Pleistocene grassland of the Columbia basin, Washington, USA, based on phytolith records in loess. Palaeogeography Palaeoecology Palaeoclimatology, 177, 77-101.

This article uses the phytolith record within three loess cores to interpret the palaeoecology of the Columbia Basin, at different altitudinal levels, during the last 100 k.y.. The phytolith data allows identication of Stipa, Poa and Festuca grasses present at the Last Glacial Maximum. One plate of SEM images is included.

Bonnett, O., 1972. Silicified cells of grasses: a major source of plant opal in Illinois. Agriculture Experiment Station Bulletin, 742.

Phytoliths from Festucoideae, Chlorideae and Panicoideae grasses and soil from Illinois were extracted and described with respect to their anatomical origin. The dispersed phytoliths in soil samples could be identified to subfamily, but not to species level. Light microscopy photographs are included.

Boyd, W., Lentfer, C. & Torrence, R., 1998. Phytolith analysis for a wet tropics environment: methodological issues and implications for the archaeology of Garua Island, West New Britain, Papua New Guinea. Palynology, 22, 213-228.

This article discusses the use of phytolith analyis to assess human response to this volatile environment. Several methodological issues are addressed including extraction, modern analogues, categorisation, preservation and statistical methods. It is noted that the degree of error would be reduced once a regional phytolith reference collection is compiled. There are no images.

Brown, D., 1984. Prospects and limits of a phytolith key for grasses in the central United States. Journal of Archaeological Science, 11, 345-368.

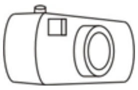
This article presents a comprehensive key to the phytoliths from 112 grass species common to central North America. Eight major shape categories are subdivided into minor shape categories with large variability. For most, size variations within species are interpreted to be the result of plant vigour. Different tribes and subfamilies differ considerably in the relative importance of bilobates, saddles and trapezoids allowing the interpretation of palaeotemperature through time with changes in C_3/C_4 phytolith ratios.

Bussell, M. & Pillans, B., 1997. Vegetational and climatic history during oxygen isotope stage 7 and early stage 6, Taranaki, New Zealand. Journal of the Royal Society of New Zealand, 27(4), 419-438.

As an appendix to this article (entitled "Phytoliths from the Ararata Gully section, Taranaki, New Zealand"), J. Carter provides additional information on vegetation changes between the last glacial and post-glacial periods from the phytolith record at this site. Loess layers (glacial) are dominated by grass phytoliths, and palaeosols (post-glacial) by tree phytoliths. The results are similar to those found by Kondo et al (1994) (see "Books" section) for the Rangitatau East Road, 50 km southeast of Ararata Gully.

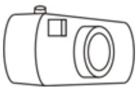
Carnelli, A., Madella, M. & Theurillat, J., 2001. Biogenic Silica Production in Selected Alpine Plant Species and Plant Communities. Annals of Botany, 87(4), 425-434.

This article describes the phytolith content of 28 alpine species in the Swiss Alps and discusses their contribution to soil phytolith assemblages.



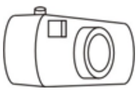
Carnelli, A., Madella, M., Theurillat, J.P. & Ammann, B., 2002. Aluminium in the opal silica reticule of phytoliths: a new tool in palaeoecological studies. American Journal of Botany, 89(2), 346-351.

This article describes an investigation into the chemical composition of both herbaceous and woody phytoliths from 20 species in the Swiss Alps. It was found that 72% of wood and leaf samples from the woody species contained aluminum in the form of aluminosilicates. This discovery has the potential to aid the interpretation of the type of source plant of phytoliths in dispersed assemblages and in conjunction with the morphological approach will help understand the shift of grasslands versus woodlands. SEM photographs are included.



Carter, J., 2002. Phytolith analysis and paleoenvironmental reconstruction from Lake Poukawa Core, Hawkes Bay, New Zealand. Global and Planetary Change, 33, 257-267.

This article presents a vegetation history using phytolith analysis from an 197 m core from Lake Poukawa in Hawkes Bay, New Zealand from marine Oxygen Isotope Stage 5 to the present. Grass/Cyperaceae grew in the warmer periods and woody taxa during the cold periods. Successional changes in vegetation from grass/Cyperaceae to trees and shrubs are shown to occur after major tephra falls. Light microscopy photographs are included.



Carter, J., 2000. Phytoliths from loess in Southland, New Zealand. New Zealand Journal of Botany, 38, 325-332.

Phytoliths are described from five loess cores from Southland, New Zealand since 24 k.y. BP. High abundances of grass and non-grass phytoliths about the Oxygen Isotope Stage 2/3 boundary suggests open woodland. A rapid change occurs above to cold-climate tussock grassland. A plate of light microscopy phytolith images is included.

Carter, J. & Lian, O., 2000. Palaeoenvironmental reconstruction from the last interglacial using phytolith analysis, southeastern North Island, New Zealand. Journal of Quaternary Science, 15(7), 733-743.

A loess core from Bidwill Hill in southeastern North Island, New Zealand provides a vegetation and climate record since c. 90 k.y. BP. Tree/shrub phytolith fluctuations appear to correlate with the SPECMAP oxygen isotope curve suggesting climate directly affected the ratio of arboreal to non-arboreal phytoliths. A plate of light microscopy phytolith images is included.

Carter, J., 1999. Late Devonian, Permian and Triassic phytoliths from Antarctica. Micropaleontology, 45(1), 56-61.

This article documents phytoliths from Beacon Supergroup sediments in the Transantarctic Mountains and are among the oldest recorded to date. Five morphotypes are described and illustrated with light microscopy images. Tentative natural affinities are presented.

Carter, J., 1998. Phytoliths from CRP-1. Terra Antartica, 5(3), 571-576.

Phytoliths are documented in this article from the CRP-1 drillhole, Cape Roberts Project, Antarctica. Nine morphotypes are described including sphericals compared to Nothofagus phytoliths and two monocotyledon forms (chionochloid and elongate). The phytolith assemblage compares well to the Miocene and Quaternary terrestrial palynology record. Two plates of light microscopy phytolith images are included.

Clarke, J., 2003. The occurrence and significance of biogenic opal in the regolith. Earth Science Reviews, 60, 175-194.

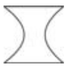
This review paper discusses the different types of opal silica (concentrating on phytoliths, diatoms and sponge spicules) in the soil and landscape as a whole. It also discusses chemical composition and biogeochemical cycling of silica. The author provides a brief, general overview of phytolith analysis and illustrates some examples with line drawings.

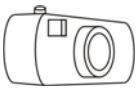
Coil, J., Korstanje, M., Archer, S. & Hastorf, C., 2003. Laboratory goals and considerations for multiple microfossil extraction in archaeology. Journal of Archaeological Science, 30(8), 991-1008.

This article reviews laboratory procedures involved in the extraction of eight microfossil types, including phytoliths. It discusses the potentially destructive effects of discrete procedures and presents two case studies of multiple microfossil extraction. Primarily aimed at archaeologists.

Conley, D., 2002. Terrestrial ecosystems and the global biogeochemical silica cycle. Global Biogeochemical Cycles, 16(4), 68-1 - 68-8.

This article highlights the relative importance of the terrestrial biogeochemical cycle and the large amounts of biogenic silica stored in living plants and subsequently being released into the soil. It suggests that this significant silica pool should be considered to effectively model weathering and global climate.





Deflandre, G., 1963. Les Phytolithaires (Ehrenberg). Protoplasma, 57, 234-259.

An early review of phytolith analysis including the history of phytolith study, a definition of what phytoliths are, their general morphology, early classification and role in soils and palaeoenvironmental reconstruction. Line drawings and light microscopy photographs accompany the text. In French.

Delhon, C., Alexandre, A., Berger, J.-F., Thiébault, S., Brochier, J.-L. & Meunier, J., 2003. Phytolith assemblages as a promising tool for reconstructing Mediterranean Holocene vegetation. Quaternary Research, 59, 48-60.

Phytoliths are described from modern and buried Holocene soils from the Rhône Valley in France. It is concluded that the main northwestern Mediterranean biomes are well distinguished by soil phytolith assemblage analysis using three phytolith indexes. This analysis helps fill an information gap about Holocene vegetation changes in this region due to the lack of other proxy preserving sites.

Elbaum, R. & Weiner, S., 2003. Detection of burning of plant materials in the archaeological record by changes in the refractive indices of siliceous phytoliths. Journal of Archaeological Science, 30, 217-226.

This article describes an investigation into the effect on refractive index of burning phytolith material. It was found that burnt phytoliths have a RI > 1.440 and can therefore be differentiated from unburnt phytoliths using a transmitted light microscope and a mineral oil of RI 1.440. In an archaeological situation, misleading results can occur in a mixed burnt/unburnt phytolith sample where the phytoliths may have degraded by a mixture of biological processes and fire.

Fearn, M., 1998. Phytoliths in sediment as indicators of grass pollen source. Review of Palaeobotany and Palynology, 103, 75-81.

This article discusses how Gramineae phytoliths can aid interpretation of soil samples and sediment cores where grass pollen is a significant component. The phytolith ratio in an estuarine core indicates whether grass pollen comes from marsh taxa or tallgrass prairie. Phytoliths can help resolve interpretation problems due to Gramineae prominence in both very dry and very wet environments. There are no images.

Fisher, R., Bourn, C. & Fisher, W., 1995. Opal phytoliths as an indicator of the floristics of prehistoric grasslands. Geoderma, 68, 243-255.

This article establishes a strong relationship between modern vegetation and the phytolith content of surface soil at four sites in the Capitol Reef National Park, Utah. Buried soil phytolith assemblages back to c.800 years ago revealed a decline in cool season grasses inconsistent with climate change, but possibly related to grazing pressures. Outline illustrations of phytolith morphotypes are included.

Fredlund, G. & Tieszen, L., 1997. Calibrating grass phytolith assemblages in climatic terms: Application to late Pleistocene assemblages from Kansas and Nebraska. Palaeogeography Palaeoclimatology Palaeoecology, 136(1-4), 199-211.

This article describes the application of a modern dataset of 34 soil phytolith assemblages across the Great Plains of North America, which are calibrated to climatic parameters. These results are then used to interpret palaeo-temperature from three late Pleistocene sites showing major change across the Pleistocene-Holocene boundary.

Fredlund, G. & Tieszen, L., 1994. Modern phytolith assemblages from the North American Great Plains. Journal of Biogeography, 21, 321-335.

Soil phytolith assemblages from across the Great Plains in central North America are shown to reflect regional grassland composition rather than local vegetation (using principal component analysis). Assemblage formation is discussed noting five main influencing factors: decay-in-place, fire, eolian transport, herbivory and fluvial/colluvial deposition. The authors also describe a method of consistently classifying the typical grass phytoliths observed in their study using three-dimensional morphology (including line drawings).

Geis, J., 1973. Biogenic silica in selected species of deciduous angiosperms. Soil Science, 116(2), 113-130.

This article describes phytoliths from 36 deciduous tree and shrub species in forest communities from the central US prairie-forest border region. A description of a wet oxidation method using sulphuric acid and hydrogen peroxide is included. Six transmitted light microscopic plates are included.

Gobetz, K. & Bozarth, S., 2001. Implications for Late Pleistocene Mastodon Diet from Opal Phytoliths in Tooth Calculus. Quaternary Research, 55, 115-122.

In this study, phytoliths extracted from the tooth calculus of modern and fossil American mastodons revealed a grass-dominated diet with a minor component of dicotyledonous hackberry (Celtis spp.) and indeterminate deciduous trees. It is suggested that these mastodons grazed in a cool, moist late Pleistocene environment, possibly near water. Eight light microscopy phytolith images are included.

Gol'yeva, A., 2001. Biomorphic analysis as a part of soil morphological investigations. Catena, 43, 217-230.

This article discusses the use of biotic remains as an assemblage or 'biomorph' that reflects soil development and landscape evolution. Biomorphs include plant tissue, detritus, phytoliths, pollen and other biotic remains. Studying palaeosols in this way can provide information about the main vegetation changes, particularly during the Holocene, including human impacts on the biomorphs. Samples from the Russian Plain provide a case study of this type of analysis.

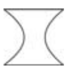
Gol'yeva, A., 1996. Experience using phytolith analysis in soil science. Eurasian Soil Science, 28(12), 248-256.

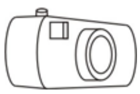
Phytolith production in 200 plants from natural phytocenoses in European Russia have been analysed and an atlas guide compiled (refer to Gol'yeva, 2001, this section). The stability and distribution of phytoliths in soils is discussed and a deluvial profile investigated. Forest and meadow assemblages are identified and a complex landscape evolution suggested. There are no phytolith images.

Hansen, B., Plew, M. & Schimpf. M., 1998. Elucidation of size patterning in phytolith assemblages by field-flow fractionation. Journal of Archaeological Science, 25, 349-357.

This article describes a high resolution technique for characterising size distributions of phytolith assemblages. The results indicate discrete size distributions in montane forest and grassland samples with the latter containing smaller, flatter particles. This technique adds a further dimension to the characterisation of complex phytolith assemblages.

Hart, D., 1990. Occurrence of the 'Cyperaceae-type' phytolith in dicotyledons. Australian Systematic Botany, 3, 745-750.





This article reports the discovery of conical hat-shaped phytoliths, previously thought to only occur in the Cyperaceae, in three dicotyledon families (Mimosaceae, Proteaceae and Casuarinaceae) in the Sydney region. This study is a reminder of the importance of modern reference collections to studies of past vegetation change and suggests that reliance on overseas experience is not necessarily valid. SEM photographs are included.

Hart, D.M., 1988. The plant opal content in the vegetation and sediment of a swamp at Oxford Falls, New South Wales, Australia. Australian Journal of Botany, 36, 159-170.

This article describes phytoliths extracted from 10 native swamp species in New South Wales, mostly of sphere, rod and sheet form. It was found that the forms with a small surface area to volume ratio survived in the sediment. However, limitations of phytolith analysis are discussed, in particular noting that a high proportion of plant opal production is in the fine silt and clay fraction that is not recovered by heavy liquid separation and that phytoliths are likely not species-specific due to their conformity to cell type morphology. SEM photographs are included.

Hart, D., 1988. Safe method for the extraction of plant opal from sediments. Search, 19, 293.

This article describes early use of a non-toxic heavy liquid to extract phytoliths from sediments. The heavy liquid recommended is sodium polytungstate and the method employed is presented in detail. The author states that it has been found to produce results comparable with other heavy liquid methods. There are no phytolith images.

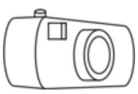
Horrocks, M., Deng, Y., Ogden, J. & Sutton, D., 2000. A reconstruction of the history of a Holocene sand dune on Great Barrier Island, northern New Zealand, using pollen and phytolith analyses. Journal of Biogeography, 27(6), 1269-1277.

This study concludes that without more specific modern analogue information only broad vegetation types can be interpreted from the phytolith record. However, by reviewing the information derived from both sources, it concludes that the simultaneous use of both methods potentially provides a powerful tool for reconstructing Quaternary coastal environments.

Horrocks, M., Irwin, G., McGlone, M., Nichol, S. & Williams, L., 2002. Pollen, phytoliths and diatoms in prehistoric coprolites from Kohika, Bay of Plenty, New Zealand. Journal of Archaeological Science, 30, 13-20.

Pollen, phytolith and diatom analyses from fossil coprolites (probably dog) suggest pre-European (pre-c.AD 1800) and post-large scale Polynesian deforestation (post-c. 700 yr BP) deposition. The phytolith assemblage is dominated by spherical verrucose tree forms and provides some information about diet and palaeoenvironmental conditions at the site and time of occupation.

Jiang, Q., 1995. Searching for evidence of early rice agriculture at prehistoric sites in China through phytolith analysis: an example from central China. Review of Palaeobotany and Palynology, 89, 481-485.

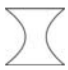


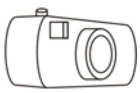
This article discusses soil samples from up to 4500 years ago at an archaeological site in central China. Three diagnostic phytolith morphotypes (illustrated with light microscopy images) indicate that rice was cultivated here well outside of its natural range. It is shown that phytolith analysis provides a useful technique for studying rice origin and dispersal.

Kealhofer, L. & Penny, D., 1998. A combined pollen and phytolith record for fourteen thousand years of vegetation change in northeastern Thailand. Review of Palaeobotany and Palynology, 103, 83-93.

This article combines pollen and phytolith data to provide the oldest continuous record of vegetation change for continental Southeast Asia. Human/environmental interaction is evident since the Early Holocene and includes fire and changes to subsistence strategies as well as climate change. There are no images.

Kealhofer, L. & Piperno, D., 1998. Opal phytoliths in Southeast Asian flora. Smithsonian Contributions to Botany, 88.





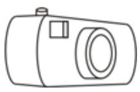
This publication presents the initial results of a modern reference collection compiled during the study of environmental and land use change in Southeast Asia (Kealhofer & Penny, 1998). This collection focuses on the Thai flora. Plant samples from nine monocotyledon families and twenty-six dicotyledon families produced diagnostic phytoliths. Light microscopy images and detailed descriptions are included.

Kelly, E., Amundson, R., Marino, B. & Deniro, M., 1991. Stable Isotope Ratios of Carbon in Phytoliths as a Quantitative Method of Monitoring Vegetation and Climate Change. Quaternary Research, 35(2), 222.

This article discusses the palaeoclimatic implications of $^{13}C/^{12}C$ ratios of occluded carbon within phytoliths from the northern Great Plains which reflect the current proportions of C_3 and C_4 plants. The ^{13}C values of soil phytoliths increase with decreasing ^{14}C age suggesting the proportion of C_4 plants has increased in this region since the Holocene. There are no phytolith images.

Kerns, B., Moore, M. & Hart, S., 2001. Estimating forest-grassland dynamics using soil phytolith assemblages and $\delta^{13}C$ of soil organic matter. Ecoscience, 8(4), 478-488.

This article examines forest-grassland vegetation dynamics using phytoliths and $\delta^{13}C$ and the relationship between contemporary vegetation and surface soil phytolith assemblages in northern Arizona. Surface soil phytolith assemblages strongly reflect vegetation within several kilometres of the sample site. Sample sites were located within open, old-growth and dense young pine canopy types. It is noted that the $\delta^{13}C$ of soil organic matter reflects long-term phytolith accumulation and that C_4 grasses may have been more abundant in the past (during subsurface soil layer deposition).



Kondo, R., 1977. Opal phytoliths, inorganic, biogenic particles in plants and soils. 11(4), 198-203.

This article discusses differences between grass and tree phytoliths from plants in Japan and their distribution in soils. SEM images are included.

Lentfer, C., 1999. An assessment of techniques for the deflocculation and removal of clays from sediments used in phytolith analysis. Journal of Archaeological Science, 26, 31-44.

This article compares two laboratory methods (sieving and centrifugation) for deflocculation and removal of clay particles during phytolith analysis. The authors recommend centrifugation as a reliable and fast method as it is a superior method to sieving. Centrifugation could be comparable to still-settling if the influence of sediment density of fluid viscosity is considered when calculating settling times.

Lentfer, C. & Boyd, W., 1998. A comparison of three methods for the extraction of phytoliths from sediments. Journal of Archaeological Science, 25, 1159-1183.

This article reviews the performance of two heavy liquid flotation and one burning method for extracting phytoliths from sediments. The results show that different methods produce different results. The authors suggest a heavy liquid flotation method using non-toxic sodium polytungstate with chemical treatments specific to sediment requirements. Outline drawings of phytolith morphotypes are included.

Lentfer, C. & Boyd, W., 2000. Simultaneous Extraction of Phytoliths, Pollen and Spores from Sediments. Journal of Archaeological Science, 27(5), 363-372.

This article presents a comparison between a standard pollen and spore processing technique using acetolyis and a heavy liquid flotation technique used for phytolith extraction. The two methods are shown to be comparable in output with the latter proving more reliable for more oxidised sediments. The combined extraction technique is described. There are no illustrations.

Lentfer, C., Cotter, M. & Boyd, W., 2003. Particle settling times for gravity sedimentation and centrifugation: a practical guide for palynologists. Journal of Archaeological Science, 30, 149-168.

This methodology article discusses optimum centrifugation times and speeds or settling times during palynological studies (particularly pollen and phytoliths). This results in suggestions for considerable time saving during laboratory procedures.

Lu, H. & Liu, K., 2003. Morphological variations of lobate phytoliths from grasses in China and the south-eastern United States. Diversity and Distributions, 9(1), 73-87.

This article describes the variability in 25 diagnostic lobate phytolith shapes from 85 modern grass species (mainly Panicoideae) in China and NE United States. A classification method is described based on morphological parameters and in some cases identification to tribe or genus is possible from the lobate phytolith shape or phytolith assemblage composition. However, in general there is a considerable amount of overlap in lobate phytolith shape from one genus to another. It is shown that variations in lobate phytolith morphology can reflect environmental factors, especially moisture, which may be important for palaeoclimate reconstruction. Light microscope 'cut-out' phytolith photographs are included.

Madella, M., Alexandre, A. & Ball, T., 2003. International Code for Phytolith Nomenclature 1.0. The Phytolitharien, 15(1), 7-16.

The article provides a draft standard protocol and a glossary of descriptors to be used in naming and describing a phytolith type. The protocol provides guidelines for a description procedure (shape, surface texture and/or ornamentation, non-surface texture features, symmetrical features, morphometric data, illustrations, anatomical origin), descriptive tools (nouns and adjectives), stating taxonomic significance and the naming of new types. The glossary includes line drawings to illustrate specific descriptors.

Madella, M., Powers-Jones, A. & Jones, M., 1998. A Simple Method of Extraction of Opal Phytoliths from Sediments Using a Non-Toxic Heavy Liquid. Journal of Archaeological Science, 25(8), 801-803.

This article describes a refined procedure for the extraction of phytoliths from sediments using sodium polytungstate. There are no illustrations.

Marx, R., Lloyd, K., Lee, D. & Lee, W., submitted. Phytolith morphology and biogenic silica concentrations and abundance in leaves of *Chionochloa* and *Festuca* (Poeae) in New Zealand. Australian Journal of Botany.

This article describes phytoliths extracted from the leaves of 34 Chionochloa (Danthonieae) and 9 Festuca (Poeae) species of New Zealand grasses. Cluster analysis and Detrended Correspondance Analysis are used to check for intra-specific consistency and for major inter-specific patterns in type and abundance. SEM plates are included and an unpublished accompanying CD-ROM was produced (refer to Marx, et al. 2003 in the 'CD-ROMs' section).

Mercader, J., Runge, F., Vrydaghs, L., Doutrelepont, H., Ewango, C. & Juan-Tresserras, J., 2000. Phytoliths from archaeological sites in the tropical forest of Ituri, Democratic Republic of Congo. Quaternary Research, 54, 102-112.

This article describes phytoliths from late Quaternary and Holocene archaeological sediments, reconstructs the vegetation and discusses the probability of prehistoric foragers inhabitation many millenia before farming began in the region. Transmitted light microscope images are included.

Meunier, J., Dominique, C. & Alarcon, C., 1999. Biogenic silica storage in soils. Geology, 27(9), 835-838.

This article describes the development of phytolith-rich soil horizons and discusses the significance of biogenic silica storage in soil with regard to weathering rates.

Mulholland, S., 1989. Phytolith shape frequencies in North Dakota grasses: a comparison to general patterns. Journal of Archaeological Science, 16, 489-511.

This comprehensive article reviews grass phytolith classification and suggests refinements based on a modern reference collection from North Dakota. Despite recognised overlap between tribes, some general statements can be made if treated with caution: 1) sinuate and rectangle phytoliths probably indicate Pooideae tribes; 2) large numbers of saddles probably indicated Chloridoideae and 3) tabular dumb-bells and crosses probably indicate Panicoideae. It is emphasised that a modern reference collection should be analysed in all cases to fully understand dispersed phytolith assemblages. SEM photographs are included.

Parr, J., 2002. A comparison of heavy liquid flotation and microwave digestion techniques for the extraction of fossil phytoliths from sediments. Review of Palaeobotany and Palynology, 120(3-4), 315-336.

This methodology article compares the relative merits of the standard heavy liquid flotation method with a new microwave digestion technique. It concludes that the microwave technique is fast and inexpensive and produces interpretable and replicable phytolith assemblage data.

Parr, J., Dolic, V., Lancaster, G. & Boyd, W., 2001. A microwave digestion method for the extraction of phytoliths from herbarium specimens. Review of Palaeobotany and Palynology, 116(3), 203-212.

This methodology article trials the microwave digestion technique for the extraction of phytoliths from modern plant material for reference material. It concludes that the microwave technique is fast, eliminates concerns of cross-contamination and produces comparable phytolith assemblages to those extracted using the conventional dry ashing technique. Light microscopy photographs are included.

Parr, J., Lentfer, C. & Boyd, W., 2001. A comparative analysis of wet and dry ashing techniques for the extraction of phytoliths from plant material. Journal of Archaeological Science, 28(8), 875-886.

This study analyses two common phytolith extraction methods and the result on the final phytolith residue. Morphometric analysis suggests that phytoliths do not shrink or warp during incineration above 450°C and that there is no significant difference between the shapes of phytoliths processed using the two different methods.

Piperno, D., 1989. The occurrence of phytoliths in the reproductive structures of selected tropical angiosperms and their significance in tropical paleoecology, paleoethnobotany and systematics. Review of Palaeobotany and Palynology, 61, 147-173.

This article describes the often distinct phytoliths from reproductive structures of tropical angiosperms. Phytoliths from these organs can be useful to identify taxa to genus, or possibly species. In combination with pollen analysis, the identification of separate taxa in, for example, the Cyperaceae, would provide valuable information about palaeoenvironments. Several light microscopy images are included.

Piperno, D., 1985. Phytolith analysis and tropical paleo-ecology: production and taxonomic significance of siliceous forms in New World plant domesticates and wild species. Review of Palaeobotany and Palynology, 45, 185-228.

This article describes diagnostic phytoliths from non-graminaceous wild and domesticated tropical plants and presents an identification key for use with archaeological and geological assemblages. SEM and light microscopy images are included.

Piperno, D., 1985. Phytolithic analysis of geological sediments from Panama. Antiquity, 59, 13-19.

This paper describes the results of a combined pollen and phytolith interpretation of vegetation change throughout a series of cores taken from lowland Panama. Mature tropical forest, marine swamp, freshwater swamp and disturbed forest communities were all recognised. There are no images.

Piperno, D. & Jones, J., 2003. Paleoecological and archaeological implications of a Late Pleistocene/Early Holocene record of vegetation and climate from the Pacific coastal plain of Panama. Quaternary Research, 59(1), 79-87.

This palaeoenvironmental study using phytolith assemblages in a core retrieved from a crater lake in Panama indicates that during the late Pleistocene a significant reduction in precipitation was the likely cause of the lake drying out and a savanna-like vegetation expansion at the expense of the tropical deciduous forest. Pollen and phytoliths suggest tropical deciduous forest encroached into the lake's watershed in the early Holocene. Evidence of burning suggests slash-and-burn cultivation c. 7500 to 7000 ^{14}C *yr BP.*

Piperno, D. & Pearsall, D., 1998. The silica bodies of tropical American grasses: morphology, taxonomy, and implications for grass systematics and fossil phytolith identification. Smithsonian Contributions to Botany, 85.

This publication describes and illustrates phytoliths from a modern reference collection of tropical American grasses. Light microscopy images are included.

Piperno, D., Pearsall, D., Benfer, R., Kealhofer, L., Zhao, Z. & Jiang, Q., 1999. Phytolith morphology. Science, 283, 1265-1266.

Letter to Science. This letter defends the identification of Cucurbita (squash) phytoliths, discusses phytolith size and taxonomic identification of phytoliths in response to a contribution by Rovner (1999) in the same volume (see later in this section).

Prebble, M., Schallenberg, M., Carter, J. & Shulmeister, J., 2002. An analysis of phytolith assemblages for the quantitative reconstruction of late Quaternary environments of the Lower Taieri Plain, Otago, South Island, New Zealand I. Modern assemblages and transfer functions. Journal of Paleolimnology, 27(4), 393-413.

This study is presented in two parts with this first article discussing an analysis of modern soil surface and sediment phytolith assemblages from 28 sites in east Otago, New Zealand from a variety of vegetation types and microclimates. There was no simple distinction between vegetation types at the different sites based on the phytolith assemblages. An important finding was that the duplicate assemblages from wetland and grassland sites were more internally consistent than from forest sites. The most useful transfer functions for palaeoenvironmental information from phytolith analysis were pH, log conductivity and annual precipitation.

Prebble, M. & Shulmeister, J., 2002. An analysis of phytolith assemblages for the quantitative reconstruction of late Quaternary environments of the Lower Taieri Plain, Otago, South Island, New Zealand II. Paleoenvironmental reconstruction. Journal of Paleolimnology, 27(4), 415-427.

This is the second article from a study of phytoliths in the Otago landscape, New Zealand. This article describes the fossil assemblage from a 155 m core from the Lower Taieri Plain. Transfer functions identified in the first article were applied to the fossil assemblage resulting in Late Glacial/Holocene precipitation and pH estimates consistent with other records from the Otago region. Estimates suggest that the mid-Holocene climate was wetter than at present.

Raeside, J., 1970. Some New Zealand plant opals. New Zealand Journal of Science, 13, 122-132.

Phytoliths from three tussock and three sedge species from New Zealand are described and illustrated with outline drawings. The minor differences between the tussock phytoliths were not sufficient for species differentiation, however, two of the sedge species produced diagnostic forms.

Romero, O., Lange, C., Swap, R. & Wefer, G., 1999. Eolian-transported freshwater diatoms and phytoliths across the equatorial Atlantic record: temporal changes in Saharan dust transport patterns. Journal of Geophysical Research, 104(C2), 3211-3222.

This article discusses wind-blown phytoliths caught in sediment traps deployed over the tropical and equatorial Atlantic. Depositional rates compared well to seasonal changes in Saharan dust transport and phytolith morphological diversity decreased with distance offshore. Five light microscopy phytolith images are included.

Rovner, I., 1999. Phytolith analysis. Science, 283, 488-489.

Letter to Science. The author questions the conclusions drawn from phytoliths with respect to agricultural origins in South America based on the difficulties of identifying phytoliths at refined taxonomic levels. This letter is replied to by Piperno et al (1999) in the same volume (see earlier in this section).

Rovner, I., 1971. Potential of opal phytoliths for use in paleoecological reconstruction. Quaternary Research, 1, 343-359.

This article reviews the phytolith content of thirty modern plant specimens and acknowledges the distinctiveness within major plant groups. Detailed methods for extraction of phytoliths from soils and plants are presented. It is suggested that phytoliths may in the future provide palaeoecological information comparable to terrestrial palynology where spores and pollen are not present. Outline drawings are included.

Runge, F., 1999. The opal phytolith inventory of soils in central Africa - quantities, shapes, classification, and spectra. Review of Palaeobotany and Palynology, 107, 23-53.

Phytoliths from soil surface and profile samples are described, classified and illustrated (SEM and light microscopy images). Phytolith spectra were suitable to characterise rainforest and grassland vegetation. A high percentage of silt-sized spherical phytoliths was found to be typical of forests.

Runge, F., 1996. Opal phytolithe in pflanzen aus dem humiden und semi-ariden Osten Afrikas und ihre Bedeutung für die Klima- und vegetationsgeschichte. Botanische Jahrbucher, 118(3), 303-363.

This article provides a comprehensive atlas (with transmitted light microscope images) of an analysis of 130 dicot species leaves from 52 different families. 47% of these plants accumulate amorphous silica in their leaves with only one species found to have a specific phytolith form. It was recognised, however, that the size and shape of siliceous skeletons are often typical in shape. In German with the abstract in English.

Runge, F., 1995. Potential of opal phytoliths for use in paleoecological reconstruction in the humid tropics of Africa. Zeitschrift fur Geomorphologie N.F., 99, 53-64.

This article discusses the use of phytolith analysis as part of a University of Päderborn project entitled "Late Quaternary landscape and vegetation dynamics in central Africa". It contains a good introduction and history of phytolith analysis. Thirty-eight tropical plants were analysed, of which ten show typical phytolith shapes and high silicification. Fossil phytoliths were recovered from soils in Zaire. Light microscopy images are included.

Sase, T., 1988. Opal phytolith analysis of present and buried volcanic ash soils at Te Ngae Road tephra section, Rotorua Basin, North Island, New Zealand. Quaternary Research, 27(3), 152-163.

In Japanese - translation not cited - abstract and figures in English. Phytoliths were examined from a tephra soil and several native New Zealand trees near Rotorua, New Zealand. Palaeoclimate interpretations are made from the phytolith assemblage back to c.20 k.y. ago. Light microscopy and SEM images are included.

Scott, L., 2002. Grassland development under glacial and interglacial conditions in southern Africa: review of pollen, phytolith and isotope evidence. Palaeogeography Palaeoclimatology Palaeoecology, 177, 47-57.

This paper reviews information about south African grasslands, establised by the Late Tertiary, from various proxies including pollen, isotopes and phytoliths. In general, temperate grassland consisted of a relatively increased C_3*- to* C_4*-grass ratio during the last glacial maximum and the presence of* C_4*-dominated grasslands in the tropics. A short section briefly reviews several studies on grass phytoliths from southern Africa. There are no phytolith illustrations.*

Sedov, S., Arias-Herreìa, A., Vallejo-Gèomez, E., Jasso-Castaneda, C., Solleiro-Rebolledo, E. & Morales-Puente, P., 2003. Mineral and organic components of the buried paleosols of the Nevado de Toluca, Central Mexico as indicators of paleoenvironments and soil evolution. Quaternary International, 106-107, 169-184.

This paper uses an analysis of phytoliths interpreted to be derived from both C_3 *and* C_4 *plants to provide evidence of wet and dry palaeoclimate oscillations during the development of Quaternary palaeosols in Central Mexico. In this study, phytolith analysis aided the refinement of palaeoclimate interpretations from a tephra-palaeosol sequence, which indicated initial contradictions between the paleopedological and lacustrine records.*

Strömberg, C., 2002. The origin and spread of grass-dominated ecosystems in the late Tertiary of North America: preliminary results concerning the evolution of hypsodonty. Palaeogeography Palaeoecology Palaeoclimatology, 177, 59-75.

Eight phytolith morphotypes are described and illustrated (SEM images) from Oligocene and Miocene sediments in northwest Nebraska. Grass forms (mainly festucoid) dominate the assemblages with woody and herbaceous dicotyledons, palms and sedges. Open C_3 *grassland between 25 and 17 Ma in the study area predates grassland adaptations in ungulates (hoofed mammals) by 7 Ma.*

Tarnocai, C., Kodama, H. & Fox, C., 1991. Characteristics and possible origin of the white layers found in the fossil forest deposits, Axel Heiberg Island, Canadian Arctic Archipelago, Northwest Territories, Canada. Bulletin of the Geological Survey of Canada, 403, 189-200.

This article describes white layers 5-50 cm thick within the Buchanan Lake Formation in the Geodetic Hills of Axel Heiberg Island. These layers contain rod-like and other irregular particles that resemble plant phytoliths. Diagenesis has transformed them to crystalline quartz losing nearly all the original morphology.

Thorn, V., 2004. Data Report: Phytoliths in drill core sediments from Sites 1165 and 1166, Leg 188, Prydz Bay, East Antarctica. Proceedings of the Ocean Drilling Program Scientific Results, 188.

This article describes rare phytoliths observed in marine sediment cores off the coast of the East Antarctica in Prydz Bay, spanning time intervals from the Late Cretaceous to latest Pleistocene. Spherical tree/shrub phytoliths are the most common forms, however, the possibility of modern contaminants is noted. Light microscopy images are included.

Thorn, V.C., 2004. Phytolith evidence for C_4-dominated grassland since the early Holocene at Long Pocket, northeast Queensland, Australia. Quaternary Research, **, **.

This article describes a Holocene C_4-grass dominated phytolith assemblage from Long Pocket, an ephemeral lake near Toomba in semi-arid northeast Queensland, Australia. Phytoliths are abundant and well-preserved in the siliceous lake fill sediments also containing diatoms and sponge spicules with very little terrestrial material and no pollen. The assemblage suggests that a C_4-dominated grassland with a minor woody component has been present in the region since c.8000 cal yr BP and that mean summer temperatures of at least 14ºC (c.10°C cooler than present) were maintained since the early Holocene. Light microscope images are included.

Thorn, V., in press. Phytoliths from subantarctic Campbell Island: plant production and soil surface spectra . Review of Palaeobotany and Palynology.

This paper describes a pilot study on phytolith production in selected species sourced from subantarctic Campbell Island. The distinctive 'megaherbs' are found to be non-producers. Soil surface samples were found to contain dispersed phytolith assemblages dominated by graminoid phytolith morphotypes.

Thorn, V., 2001. Oligocene and early Miocene phytoliths from CRP-2/2A & CRP-3, Victoria Land Basin, Antarctica. Terra Antartica, 8(4), 407-422.

This article describes Cenozoic phytoliths throughout two marine cores drilled off Cape Roberts in the Ross Sea region of Antarctica. Phytoliths are compared tentatively to modern analogues and supplement the terrestrial palynomorph interpretation with occurrences of grass and palm phytoliths. Two plates of light microscopy images are included.

Twiss, P., Suess, E. & Smith, R., 1969. Morphological classification of grass phytoliths. Proceedings of the Soil Society of America, 33, 109-115.

This article presents an early attempt at classifying grass phytoliths into four classes and 26 types, which distinguish three subfamily groups of Poaceae: Festucoid, Chloridoid and Panicoid. Light microscopy images and line illustrations are included.

Wallis, L., 2003. An overview of leaf phytolith production patterns in selected northwest Australian flora. Review of Palaeobotany and Palynology, 125, 201-248.

This substantial paper presents the results from a modern reference collection study of phytoliths in predominantly the leaves of 177 non-Poaceae species from northwest Australia. Approximately half of the species studied were non-phytolith producers and a range of distinctive and redundant forms were observed in the producer species. It is suggested that both genetic and environmental controls influence phytolith production. SEM images are included.

Wallis, L., 2001. Environmental history of northwest Australia based on phytolith analysis at Carpenter's Gap 1. Quaternary International, 83-85, 103-117.

This article examines Quaternary vegetation and climate history in northwestern Australia since c.40 k.y. BP from Carpenters Gap 1 archaeological site. Grass and non-grass phytoliths were present in the sediments in approximately equal proportions. A modern reference collection of c.350 regional plant specimens (53 families) was examined with approximately half producing phytoliths. There are no images.

Webb, E. & Longstaffe, F., 2003. The relationship between phytolith- and plant-water ✤^{18}O values in grasses. Geochimica et Cosmochimica Acta, 67(8), 1437-1449.

This article describes an experiment measuring the variability in $\delta^{18}O$ values within different plant organs of two species of grass: Ammophila breviligulata (C_3) and Calamovilfa longifolia (C_4) at Pinery Provincial Park in southwestern Ontario, Canada. The $\delta^{18}O$ values are dependant on soil-water values, relative humidity, evapotranspiration rates and temperature and, if preserved in the oxygen-isotope ratio of phytoliths deposited in grasses, can provide climatic information during the period of growth.

Webb, E. & Longstaffe, F., 2002. Climatic influences on the oxygen isotopic composition of biogenic silica in prairie grass. Geochimica et Cosmochimica Acta, 66(11), 1891-1904.

This study investigated the relationship between the oxygen-isotope composition of grass phytoliths from Calamovilfa longifolia across the North American Great Plains and relative humidity, temperature, and the oxygen-18 enrichment of soil water relative to local precipitation. It was found that the overall oxygen-isotope composition of a soil-phytolith assemblage can be related to temperature with an empirical relationship between temperature, soil-phytolith and estimated soil-water oxygen-isotope compositions.

Webb, E. & Longstaffe, F., 2000. The oxygen isotopic compositions of silica phytoliths and plant water in grasses: implications for the study of paleoclimate. Geochimica et Cosmochimica Acta, 64(5), 767-780.

This article describes a study in southwestern Ontario of $\delta^{18}O$ levels in phytoliths from various C_3 and C_4 grass plant parts and plant-water. Natural and greenhouse sites were investigated. Isotopic temperatures matched measured growing temperatures for the region indicating the potential for valuable palaeoclimate data from fossil phytoliths. There are no phytolith images.

Whang, S. & Hill, R., 1995. Phytolith analysis in leaves of extant and fossil populations of *Nothofagus* subgenus *Lophozonia*. Australian Systematic Botany, 8, 1055-1065.

Herbarium, living and fossil specimens of Nothofagus leaves were examined for phytoliths. Evergreen and deciduous species can be distinguished, however, the deciduous species contain varied morphotypes. The Oligocene population of N. tasmanica R.S. Hill had poorly preserved phytoliths perhaps due to taphonomic processes or phylogenetic differences. Two clear plates of SEM images are included.

Zhao, Z. & Pearsall, D., 1998. Experiments for improving phytolith extraction from soils. Journal of Archaeological Science, 25, 587-598.

This article reviews the use of four different heavy liquids for the extraction of phytoliths from soil samples. Sodium polytungstate is recommended for use as it is non-toxic, but the pureness of extraction is poor compared to the other heavy liquids. Modifications to common procedures are suggested when removing certain oxides, during dispersion and in the sequence of processing steps.

CD-ROMs

Ball, T., unpublished. Dhofar phytoliths.

This unpublished CD-ROM contains light microscope images of phytoliths classified by morphological type produced by plants in the Oman region and was compiled in 2002. Contact the author for availability: tbball@byu.edu.

Ball, T., unpublished. The Phytolitharien - Vols. 1-13. The Society for Phytolith Research.

This CD-ROM contains MS Word files of past issues of 'The Phytolitharien'; the newsletter of The Society for Phytolith Research. Issues are included from Fall, 1981 until February 2001. Contact the compiler for availability: tbball@byu.edu.

Marx, R., Lloyd, K., Lee, D. & Lee, W., unpublished. Phytolith morphology and biogenic silica concentrations and abundance in leaves of *Chionochloa* and *Festuca* (Poeae) in New Zealand. University of Otago, Dunedin, New Zealand.

This unpublished CD-ROM contains SEM images of grass phytoliths extracted from the leaves of Chionochloa and Festuca species from New Zealand. The images are classified by species and include thumbnail contact images for quick reference. It accompanies a manuscript submitted to the Australian Journal of Botany by the same authors in 2003.

Runge, F., unpublished. Leaf phytoliths and silica skeletons from East African plants. Physical Geography, University of Päderborn, Germany, Päderborn.

This CD-ROM holds light microscopy phytolith images in Corel Photo-Paint 9 format and was compiled in 1996. Each image is a separate file with other files containing pertinent information. Contact the author for availability: freya.runge@talknet.de.

Bennett, K., 1997. Psimpoll. Quaternary Geology, Uppsala University, Uppsala, Sweden. Download from http://www.kv.geo.uu.se/psimpoll.html (Accessed 16/12/2003). Freeware.

Psimpoll reads data files to produce PostScript for printing a pollen diagram and can be used similarly for phytolith analysis. It is available for PC (DOS, Windows 3.1/95/NT) and Mac. The manual and software can be downloaded from the web-site. Psimpoll presents stratigraphic data in a similar manner to Tilia-Graph.

Covington, M., 1996. Free BugWin 96. The Natural History Museum, London. Download from http://jerwood.nhm.ac.uk/archives/paleonet/1996/msg01131.html (Accessed 16/12/2003). Free for academic use only.

BugWin is a Windows program designed to enter biostratigraphic data from well or outcrop samples and automatically draw range charts using MS Excel.

Dupont, L., 2002. PanCount. University of Bremen, Bremen, Germany. Download from http://www.pangaea.de/Software/ (Accessed 16/12/2003). Freeware.

PanCount is an Excel spreadsheet that allows you to use your keyboard as a counting device.

Grimm, E., 2000. Tilia & Tilia-Graph. National Oceanic and Atmospheric Administration, National Geophysical Data Center, Boulder, Colorado. Download from http://www.ngdc.noaa.gov/paleo/tilia.html (Accessed 16/12/2003). Tilia = freeware; Tilia-Graph = US$250.

This software was developed by Dr. Eric Grimm of the Illinois State Museum and is designed to record and display stratigraphic data. The software can be downloaded from this site and support is also provided. Support is also provided on the University of Missouri Phytolith Database web-site (Pearsall et al, 1998, refer to ''Web-sites' section).

Web-sites

Ball, T., 2002. Terry Ball's Phytolith Page.
http://home.byu.net/~tbb/index.html (Accessed 21/06/2004).

This page currently contains links to 53 (mainly SEM) images of grass phytoliths from seven genera. There are no descriptions.

Blinnikov, M., 1999. M. Blinnikov's Phytolith Gallery. Department of Geography, St Cloud State University, Minnesota.
http://coss.stcloudstate.edu/mblinnikov/phd/phyt.html (Accessed 16/12/2003).

This web-site hosts a gallery of both SEM and light microscopy phytolith images from plants in the Pacific Northwest. Phytoliths are listed by form or species and include grasses and trees/shrubs. A brief key is included and some background information on phytolith analysis.

Mulder, C., 1999. Ecological significance of grass leaf phytoliths from southern Africa. Laboratory of Palaeobotany and Palynology, Section of Botanical Palaeoecology , Department of Geobiology, Faculty of Biology, Utrecht University, The Netherlands.
http://www.bio.uu.nl/~palaeo/Research/Namibia/namibia.htm
(Accessed 16/12/2003).

This web-site briefly discusses the value of phytoliths in palaeoenvironmental reconstruction and current research including the phytolith record in offshore sediments of the Congo Fan, soil samples from the Okavango Delta in relation to C_3/C_4 *interpretations and modern herbarium and Okavango grass phytoliths. Colour light microscopy images of in-situ and ex-situ grass phytoliths are included.*

Mulholland, S., 2001. Phytolith Bibliography. About, Inc.
http://archaeology.about.com/blphytobib.htm (Accessed 16/12/2003).

This web-site (27 references, 1 p.), although intended for school children, contains a variety of phytolith references pertaining mainly to archaeological applications, but also studies on modern plants, palaeoecology, statistics and experimental analyses including isotopes and radiocarbon dating.

Pearsall, D., Biddle, A., Chandler-Ezell, K., Collins, S., Stewart, S., Vientimilla, C., Zhijun Zhao & Duncan, N., 1998. Phytoliths in the Flora of Ecuador: the University of Missouri Online Phytolith Database. http://www.missouri.edu/~phyto/ (Accessed 16/12/2003).

This database is a valuable resource containing currently 212 images and detailed descriptions searchable by Family, Genus or MU reference number. The project focuses on providing modern analogues from the flora of Ecuador. Tables are also provided of general patterns of phytolith production in different plant groups.

Zucol, A., Bertoldi de Pomar, H., Osterrieth, M. & Brea, M., 1999. Bibliografía Sobre Análisis Fitolíticos. Fitolíticas (Grupo de Estudios Fitoliticos Aplicado del Cono Sur). http://www.arcride.edu.ar/gefacs/fitoliticas1.pdf (Accessed 16/12/2003).

This web-accessed pdf file (43 pages) consists of a comprehensive bibliography of many aspects of phytolith analysis including international articles. The introduction is in Spanish.

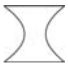
Reports

Gol'yeva, A., 2001. Phytoliths and their information role in natural and archaeological objects. Russian Academy of Sciences, Moscow.

This monograph contains information on the distribution of phytoliths in soils within the European Territory of Russia and SEM plates. Chapters: Biogenic silica in plants; The techniques of phytolith separation and study; Biogenic silica in soils; Phytolith analysis with respect to understanding soil genesis and evolution and palaeoenvironment; Phytoliths in archeological objects. The text is primarily in Russian with English language contents, summary and references.

Runge, F. & Niggemann, I., unpublished. Bibliographie der Phytolithkunde, FB 1. Universität Paderborn, Paderborn.

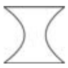
This comprehensive bibliography (64 pages) covers all aspects of phytolith research. This reference refers to the version last updated in May, 2001. Contact the author for availability: freya.runge@talknet.de.

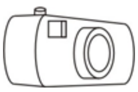


Weatherhead, A., 1988. The occurrence of Plant Opal in New Zealand soils, New Zealand Soil Bureau, Department of Scientific and Industrial Research, Lower Hutt,108.

This report describes and illustrates (outline drawings) phytoliths classified into silt (2-20 mm) and sand-sized (> 20 mm) fractions from New Zealand soils. It also discusses scanning electron microscopy of phytoliths and their distribution in soils.

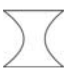
Australasian Theses

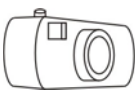




Bleakley, N., 1996. Siliceous microfossils on Mount Feather and Table Mountain, Antarctica and their origin. M.Sc. Thesis, Victoria University of Wellington, New Zealand.

Phytoliths are described from Sirius Group till and snow samples collected from Mt Feather and Table Mountain, Antarctica. It is suggested the majority of the forms are derived from grasses with rare tree and fern forms. The high abundance of specimens observed is interpreted as evidence of a glaciogenic rather than an eolian origin.





Bowdery, D., 1996. Phytolith analysis applied to archaeological sites in the Australian arid zone. Ph.D. Thesis, The Australian National University, Canberra.

Refer to 'Books & Conference Proceedings' section for description of published thesis.

Prebble, M., 2001. A phytolith analysis-based paleoenvironmental interpretation of the Lower Taieri Plain, Otago, New Zealand. M.Sc. Thesis, Victoria University of New Zealand, Wellington, New Zealand.

This thesis consists of three manuscripts that investigate the feasibility of developing quantitative climate proxies from phytoliths and applies these proxies to a late Quaternary core from the Lower Taieri Plain, New Zealand. Climate estimates are made from modern plant and sediment phytolith assemblages, vegetation change is interpreted from phytolith analysis of the core and new transfer functions are applied. There is one plate of light microscopy phytolith images.

Wallis, L., 2000. Phytoliths, late Quaternary environment and archaeology in tropical semi-arid northwest Australia. Ph.D. Thesis, The Australian National University, Canberra.

This thesis includes an extensive modern reference collection from the semi-arid Kimberley region in NW Australia (338 specimens from 54 famillies). Phytolith analysis from modern sediments suggests that a number of distinct vegetation communities and environments can be identified on the basis of the associated dispersed phytolith assemblages. An archaeological investigation at Carpenters Gap concludes the study with information about Aboriginal plant exploitation and palaeoclimate.

Part 2: Selected Subantarctic/Subalpine Modern Phytolith Atlas

Introduction

The second part of this publication provides the initial stage of a modern phytolith reference collection for the New Zealand region providing essential information for the valid interpretation of dispersed soil and sediment assemblages.

The project associated with this collection focused on the study of phytolith production in plants growing within the New Zealand subantarctic and subalpine zones in an effort to provide modern analogue information for dispersed sediment assemblages described from the Cape Roberts Project and Prydz Bay Ocean Drilling Program Leg 188 Antarctic margin cores (Carter 1998; Thorn 2001, 2004). Additional Cenozoic sediment samples from other localities around the Antarctic margin were found to be barren of phytoliths (Table 1).

Plant samples were sourced from Auckland and Campbell Islands, an Invercargill subantarctic plant collection, the grounds and herbarium at Victoria University of Wellington, and both the Otari and Wellington Botanic Gardens in Wellington. A related sample is the only grass growing on the Antarctic continent (*Deschampsia antarctica)* from the Antarctic Peninsula. Taxonomic, collection details, biogenic silica content and phytolith morphotypes observed are all presented for each phytolith-producing species together with light microscopy images.

Table 2 lists of all the plant species processed and whether phytoliths were extracted. Due to the potential lodgement of air or soil borne phytoliths into crevices within the plant samples during life, there are inevitable contaminants in the biogenic silica residue, despite careful pre-processing, cleaning procedures in the laboratory. However, the phytoliths that are produced by the plant, if there are any, are generally obvious due to their consistency and abundance throughout the sample compared to rare, inconsistent, probable contaminant, forms. From the collection processed, approximately 30% are phytolith-producing species, a figure just slightly lower than studies overseas, which generally indicate approximately 50% producer species (e.g. Wallis, 2003 and Runge, 1996). Further, the proportion of biogenic silica present in the plant tissue also varies between negligible and 5.4%.

Phytolith terminology is primarily based on the classification schemes of Mulholland & Rapp (1992), Fredlund & Tieszen (1994) and Piperno (1984).

The laboratory procedures utilized during this project for extracting phytoliths from plant, soil and sediment material in the laboratories at the School of Earth Sciences are outlined in the following pages.

Table 1
Cenozoic Antarctic margin sediments investigated for phytolith content during this study. No phytoliths were observed in the samples analysed.

Locality	No. of samples	Stratigraphic/lithologic information	Notes
Mt Discovery, McMurdo Sound, Ross Sea region	3	Middle to late Eocene, mudstone & sandstone	Radiolarian cores, diatoms.
Oliver Bluffs, Beardmore Glacier, Transantarctic Mountains	3	Meyer Desert Formation, Sirius Group	Rounded siliceous grains, some opaque. Misc. rectangular, polygonal siliceous grains.
Prince Charles Mountains. East Antarctica	2	Mt Johnston Formation, Oligocene-early Miocene	Low relief plates, misc. siliceous grains.
	3	Fisher Bench Formation, mid-Miocene	? One spherical phytolith, nodular. Low relief siliceous plates.
	5	Bardin Bluffs Formation, Pliocene/early Pleistocene	Organic-walled trachied (uniseriate bordered pits – conifer?)
	5	Battye Glacier Formation, mid Miocene	Diatoms, sponge spicules.
Seymour Island, Antarctic Peninsula	3	Sobral Formation, early Palaeocene	Misc. silica, rare thin-walled, hollow, collapsed spherical objects. Rare spicule fragments.
	2	La Meseta Formation, late early Eocene	Needle-like spicule fragments, misc. silica. Silicified pollen (?*Nothofagus* sp.). Low relief, polygonal plates, some organic-walled pollen grains, tracheids.
	8	La Meseta Formation, mid-upper Eocene	Needle-like material. ?One spherical phytolith, irregular. Rare silicified pollen (*Nothofagus* sp. and podocarp). Misc. silica. Low relief polygonal plates, nodular grains. Rounded siliceous grains. Hollow, silicified thin-walled, spherical bodies.

Table 2
List of modern plant species processed for phytoliths during this study.

Division	Subdivision	Class	Order	Family	Subfamily	Species	Phytolith producer?	Plant origin
Tracheophyta	Gymnospermopsida		Coniferales	Araucariaceae		*Araucaria bidwillii*	N	WBG
	Filicopsida		Filicales	Dryopteridaceae		*Polystichum vestitum*	N	CI/OBG
				Pteridaceae		*Histiopteris incisa*	N	OBG
	Angiospermophytina	Liliopsida (monocotyledons)	Liliales	Liliaceae		*Bulbinella rossii*	N	CI
			Poales	Cyperaceae		*Carex trifida*	Y	AI
				Poaceae	Arundinoideae	*Chionochloa antarctica*	Y	CI
					Pooideae	*Deschampsia antarctica*	Y	AP
						Poa litorosa	Y	AI
						Poa sp.	Y	CI
		Magnoliopsida (dicotyledons)	Apiales	Araliaceae		*Stilbocarpa polaris*	N	CI
			Lamiales	Boraginaceae		*Myosotis capitata*	Y	AI
			Asterales	Compositae/Asteraceae		*Anaphalioides bellioides*	Y	OBG
						Pleurophyllum criniferum	N	CI
						Pleurophyllum hookeri	N	CI
						Pleurophyllum speciosum	N	CI
			Ericales	Epacridaceae		*Dracophyllum longifolium*	N	CI
						Dracophyllum scoparium	N/Y	CI/?AI
			Scrophulariales	Scrophulariaceae		*Hebe benthamii*	N	VUWH
						Hebe elliptica	Y	VUW
						Hebe odora	N	VUW
			Primulales	Myrsinaceae		*Myrsine divaricata*	N	CI/OBG
			Rosales	Rosaceae		*Acaena anserinifolia*	Y	OBG
						Acaena minor var. *antarctica*	Y	OBG
						Acaena novae-zelandiae	Y	OBG
			Rubiales	Rubiaceae		*Coprosma rugosa*	N	OBG
						Coprosma sp.	N	CI
			Umbellales	Umbelliferae		*Anisotome antipoda*	N	CI
						Anisotome latifolia	N	CI

AI = Auckland Islands; AP = Antarctic Peninsula; CI = Campbell Island; OBG = Otari Botanic Gardens; WBG = Wellington Botanic Gardens; VUW = Victoria University of Wellington grounds; VUWH = Victoria University of Wellington Herbarium

Note:

1. Where two plant origin localities are presented, duplicate samples of that species have been processed.
2. Actual collection localities commonly differ from plant origin due to transfer of plant during growth to botanical gardens or parks (refer to individual species information for details).
3. Shaded cells highlight species that produce distinctive phytoliths.

Phytolith Extraction Methods

Vanessa Thorn & John Carter

<u>Be Safe: Always wear lab coat and do not wear open-toed shoes</u>

Geological Sediments

Sample Preparation: Sedimentology Lab

1. Select 8 x 400ml glass beakers and 8 sediment samples for processing
2. Thoroughly wash (using scourer and detergent) and rinse in both tap and then Millipore water
3. DO NOT DRY INSIDE – avoids contamination from paper towels
4. Label sequentially using a permanent waterproof marker
5. Repeat for each sample:
    - Crush consolidated sediment into < 1 cm^3 blocks using pestle and mortar
    - Place empty beaker on electronic scales and zero (note beaker and sample number)
    - Spoon ~10g of crushed sediment into beaker using clean spatula
    - Note weight of sample
    - Clean and rinse spatula, pestle and mortar with Millipore water before transferring next sample
6. *Optional* – oven dry overnight (covered with watch-glass), then record dry weight prior to next step.

Removal of organics and initial disaggregation: Sedimentology Lab

7. Put on safety glasses and disposable gloves
8. Pour ~200ml H_2O_2 (hydrogen peroxide) into each beaker
9. Leave for ~1 hour in cold water bath
10. If reaction NOT extreme, turn on water bath to 60°C (ensure water running)
11. Leave until effervescence has ceased or is minimal [1] [2]
12. Wash thoroughly white centrifuge tubs, as per Step 2
13. Repeat per sample:
    - Pour sample into tub
    - Use scales to fill tub up to mark with Millipore water

[1] At end of working day, turn water bath off, but leave beakers in, covered with a watch-glass or plastic film (e.g. Parafilm).

[2] If effervescence has not ceased after ~24 hours, remove from bath and continue with processing. Schulze's solution will remove the remaining organic material.

- All four tubs must weigh within 0.1g of each other (use disposable pipette)
- Centrifuge – press start – pre-programmed for 10 mins
- Pour off supernatant carefully
- Repeat twice more per sample

14. Thoroughly clean original beakers as per Step 2
15. Return residue to cleaned original beaker
16. Fill each beaker to ~300ml with Millipore water

Disaggregation of clay aggregates: Ultrasonic Probe - 5th Floor Soil Lab

17. Use ultrasonic probe to disaggregate (see Karyn) – 5 mins per sample
18. Rinse probe between samples with Millipore water

Removal of > 250 μm fraction: Sedimentology Lab

19. Filter each sample using 250 μm cloth:
    - Rinse and mount plastic funnel on stand with clamps
    - Wash thoroughly, as per Step 2, 8 x 1 litre glass beakers and watch-glasses (or use Parafilm or a plastic lidded crate)
    - Label sequentially
    - Place mounted filter cloth in funnel and litre beaker underneath
    - Wash sample through with Millipore water
    - Make supernatant up to ~500ml by continued water pressure on sieve
    - Remove sieve and rinse funnel thoroughly with Millipore water
    - Place litre beaker into crate or cover with watch-glass or Parafilm
    - Rinse >250μm fraction on sieve cloth into original 400ml beaker
    - Pour off excess water and dry residue under heat lamp
    - When dry and cool, bag and label in small sample bags
    - Thoroughly wash sieve cloth with high pressure tap water
20. Leave litre beakers for 1 hour (begin timing when last beaker filled) for clay separation. Keep track of 4 beakers at a time.
21. Carefully pour off supernatant, swirl residue around then refill to ~500ml
22. Leave for a further hour
23. Repeat until supernatant is clear then pour off as much as possible

Removal of remaining organics and minerals - Schulze's: Palynology Lab

24. Wash thoroughly, as per Step 2 (but using a bottle brush), 8 x 50ml polypropylene centrifuge tubes
25. Label appropriately
26. Decant residue into tubes

27. Centrifuge, in batches if necessary, @ 5000rpm for 5 mins, to remove as much water as possible
28. In fume cupboard and wearing safety glasses and disposable gloves, mix up Schulze's solution (250ml nitric acid, 50ml potassium chlorate)[3]
29. Turn on water bath in fume cupboard to red mark with test tube rack in
30. Fill each tube with ~30ml of Schulze's solution
31. Put lid on and agitate
32. Remove lid and place in water bath rack, as spaced out as possible from the other tubes
33. Leave for ~1 hour then turn water bath off – check water level in bath regularly and top up if necessary
34. Leave tubes to cool for another ½ hour
35. Centrifuge, @ 5000rpm for 5 mins, and decant supernatant
36. Wash three times, as above, in Millipore water

Flotation of biogenic silica – Sodium Polytungstate heavy liquid: Palynology Lab

37. Prepare ~200ml of sodium polytungstate at 2.3 s.g.
38. Pour 25ml sodium polytungstate into tubes and agitate with lid on
39. Centrifuge @ 2000rpm for 15 mins
40. Label new blood tubes and disposable pipettes
41. Pipette off upper 2 mm into blood tube until original polypropylene tube ~20ml full
42. Fill remainder of blood tube with millipore water and agitate
43. Centrifuge @ 5000rpm for 5 mins
44. Pour supernatant into recycling bottle
45. Repeat Steps 41-44 until as much of floating residue is recovered
46. Wash minimum of 5 times as per Step 43 (do not need to recover supernatant after first wash)
47. Depending on amount of residue decant off last batch of supernatant to reach approx. desired mounting concentration.

Microscope slide preparation: Sedimentology Lab

48. Turn on hot plate – highest temperature and leave a note indicating it is on
49. Line up and label disposable pipettes on a paper towel
50. Label a sheet of A3 paper for each of 8 samples and place cover slips against the labels under heat lamps
51. Put 4-8 drops of Millipore water onto each cover slip depending on concentration of residue

[3] Use large glass measuring cylinders and pour both into a 400ml beaker that has been cleaned thoroughly as before. Easiest to pour from large nitric acid bottle in sink. Rinse off and dry with a paper towel outside of bottle when finished before replacing back on shelf. Rinse out measuring cylinders and beakers under running water (leave water running throughout), then Millipore water before draining.

52. Shake each tube and using a clean pipette for each sample drop 1 drop of residue from bottom of tube onto cover slip – stir in using pipette
53. Turn on heat lamps and evaporate off
54. Label slide and put on hot plate
55. Use stirrer to melt a thin layer of Canada Balsam (just big enough for cover slip) onto slide – hold in place using mounting needle
56. Place cover slip on Canada Balsam
57. Tweak with mounting needle to remove air bubbles and leave on hot plate for ~ 1 hour to set

Equipment list (other equipment required all found in labs):

8 x 400ml glass beakers
8 x glass watch-glasses to fit 400ml beakers / Parafilm / 2 plastic lidded crates
1 x 600ml glass beaker
8 x 1000ml glass beakers
8 x glass watch-glasses to fit 1000ml beakers / Parafilm / 2 plastic lidded crates
Permanent marker pen
8 x 50ml polypropylene test tubes with lids & disposal blood tubes

Modern Plants

Sample preparation: Sedimentology Lab

1. Wash and rinse out in Millipore water a 500ml flask
2. Dry flask in oven

5th floor Soil Lab

3. Cut approximately 5 g of fresh plant material and add to flask – retain some of sample if possible for replicate processing (weigh on scale in soil lab to four decimal places).

Removal of adhering particles and minerals: Sedimentology Lab

4. Make up 3% HCl solution
5. Add 300ml of 3% HCl to flask
6. Suspend in ultrasonic tank using clamp and stand, switch on and leave for 15 minutes (this removes adhering particles and minerals)
7. Remove flask and carefully pour acid solution down sink with water running4
8. Fill flask with Millipore water, swirl around and pour off
9. Repeat twice
10. Place in oven to dry, use microscope slide and then cover glass over flask top to ensure no contamination from oven

5th floor Soil Lab

11. Re-weigh dried sample in flask

Digestion of organic matter: Palynology Lab

12. Locate and half fill water bath in fume cupboard; turn dial to a vertical position and switch on
13. Put on safety goggles and ensure wearing lab gloves and coat
14. Pour approximately 100ml concentrated (98%) sulphuric acid into flask. Ensure plant material is sufficiently covered.
15. Put flask into water bath.

[4] Use a cover glass to prevent plant material leaving flask

****Check water level in bath at regular intervals (every half hour)****

16. After 4 hours, turn off water bath and leave flasks to cool overnight.
17. One flask at a time, pour in H2O2 VERY CAREFULLY AND SLOWLY until the supernatant is clear, then leave for a couple of hours. ***The initial reaction will be extremely effervescent and exothermic***. If the supernatant remains yellow then turn on the waterbath and leave for a couple of hours until it becomes almost colourless.

Washing and drying residue

18. Weigh 2 dry centrifuge tubes (with lids) to 4 d.p.
19. Wash and rinse out with Millipore water 8 centrifuge tubes (including the weighed ones).
20. Progressively decant supernatant (swirling carefully within flask and rinsing flask walls to ensure all material is recovered) into the 8 tubes, using Millipore water, centrifuge and pour off supernatant until residue thoroughly washed and in one previously weighed tube only.
21. Dry tube and residue in oven in a rack with an upended beaker over the top to prevent contamination.
22. Reweigh dry tube and residue to 4 d.p. and subtract original tube weight to obtain residue weight.
23. Slide preparation – Sedimentology Lab (see Geological Sediment preparation notes above).

Organic-rich Soil

Sieving: Sedimentology Lab

1. Dry soil sample in oven overnight if necessary
2. Wash and dry (in oven) soil sieve –0.25ϕ with lid and base
3. Pick out oversized organic fragments from sample and bag up separately
4. Use pestle and mortar to gentle crush sample
5. Shake in sieve
6. Transfer <–0.25ϕ portion into glass flask of known weight
7. Transfer >–0.25ϕ portion into bag with oversized fragments
8. Weigh dried sample in flask to 4 d.p.

Digestion of organic matter: Palynology Lab

9. Do Steps 11-20 as per Modern Plant procedure above

Carbonate mineral dissolution

10. Wash residue in 10% HCl solution (make up 20ml 36% HCl with 52ml Millipore water)
11. Wash residue in Millipore water 3 times

Biogenic silica separation – heavy liquid flotation

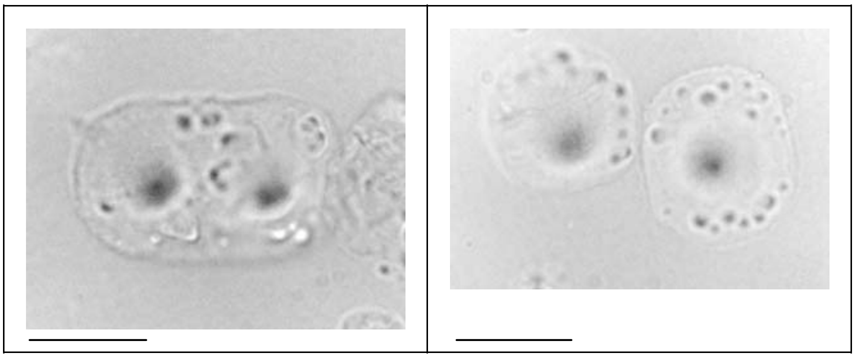
12. Pour off as much water as possible, then add 25ml of NaPoly
13. Agitate, then centrifuge for 15 minutes at 2000 rpm
14. Wash 6 times using Millipore water – recycle the supernatant from the first wash only
15. Do Steps 21 & 22.

Microscope Slide preparation – Sedimentology lab (see Geological Sediment preparation notes above)

Cyperaceae *Carex trifida*

Tracheophyta, Angiospermophytina, Liliopsida, Poales Sedge

Plant origin:	Auckland Island
Collected from:	Queen’s Park, Invercargill
Collected by:	Keith Dudfield, Invercargill City Council
Collection date:	July 2002
Identified by:	Keith Dudfield, Invercargill City Council
Silica % of dried plant:	0.2
Morphotypes recognised:	Hat-shaped, mesophyll



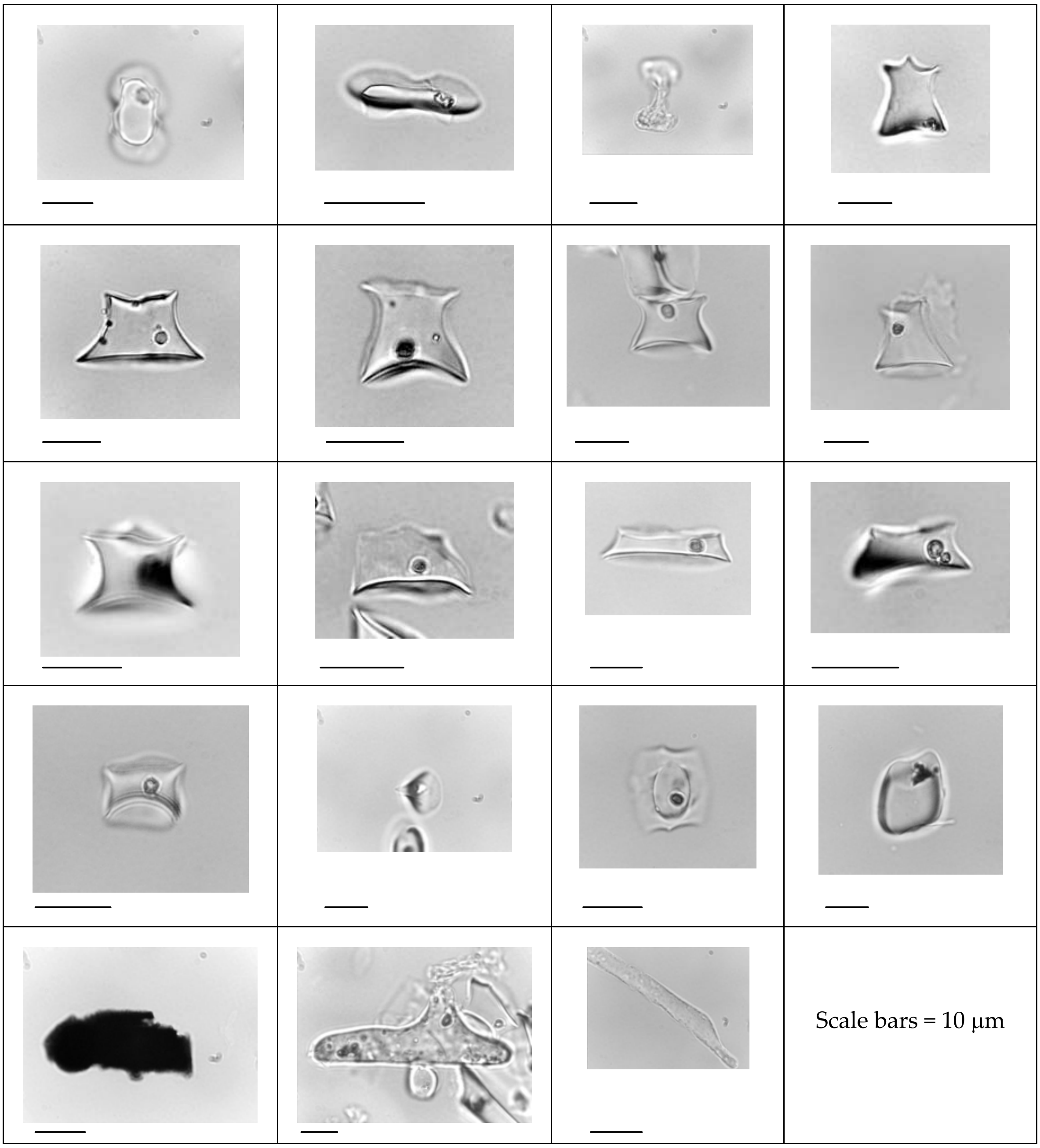
Scale bars = 10 μm

Poaceae, Arundinoideae *Chionochloa antarctica*

Tracheophyta, Angiospermophytina, Liliopsida, Poales Grass

Plant origin:	Campbell Island
Collected from:	Campbell Island
Collected by:	Carol West, Department of Conservation
Collection date:	January 1995
Identified by:	Carol West, Department of Conservation
Silica % of dried plant:	0.6

Morphotypes recognised: Bilobate, rondel, saddle, irregular, elongate

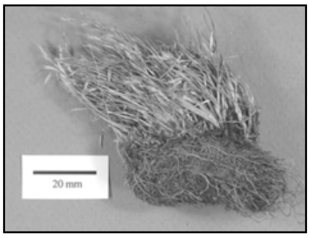


Scale bars = 10 µm

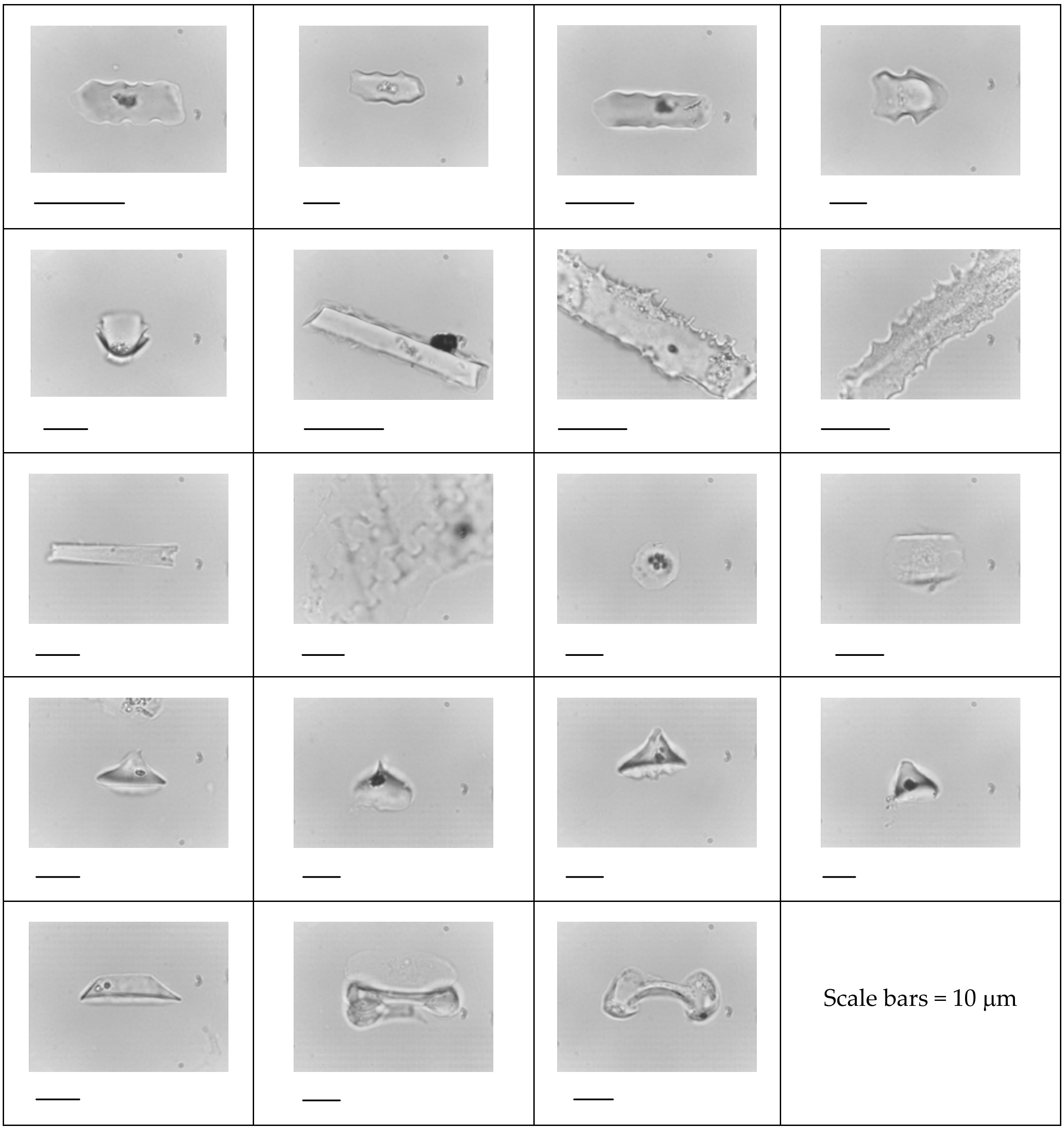
Poaceae, Pooideae *Deschampsia antarctica*

Tracheophyta, Angiospermophytina, Liliopsida, Poales Grass

Plant origin:	Antarctic Peninsula
Collected from:	Antarctic Peninsula
Collected by:	John Smellie, British Antarctic Survey
Collection date:	January 2002
Identified by:	John Smellie, British Antarctic Survey
Silica % of dried plant:	0.2



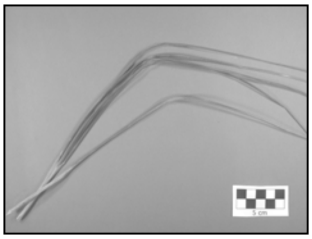
Morphotypes recognised: Polylobate, elongate, plate, rondel, bilobate



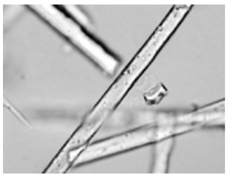
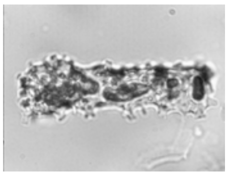
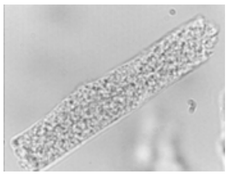
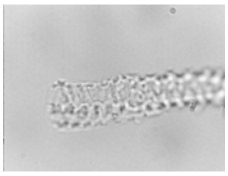
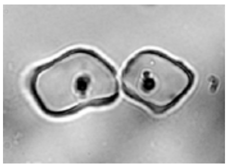
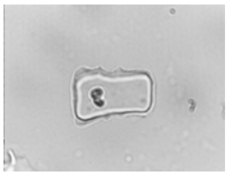
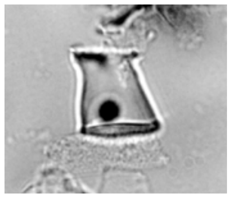
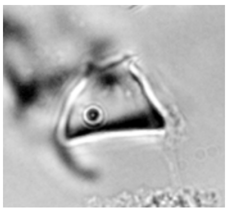
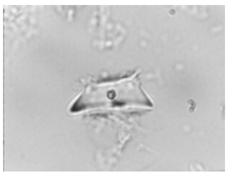
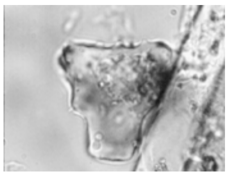
Scale bars = 10 μm

Poaceae, Pooideae *Poa litorosa*

Tracheophyta, Angiospermophytina, Liliopsida, Poales Grass



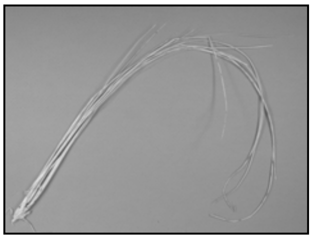
Plant origin:	Auckland Island
Collected from:	Queen's Park, Invercargill
Collected by:	Keith Dudfield, Invercargill City Council
Collection date:	July 2002
Identified by:	Keith Dudfield, Invercargill City Council
Silica % of dried plant:	2.3
Morphotypes recognised:	Rondel, saddle, irregular, elongate

			
			
			Scale bars = 10 µm

Poaceae, Pooideae ***Poa* sp.**

Tracheophyta, Angiospermophytina, Liliopsida, Poales

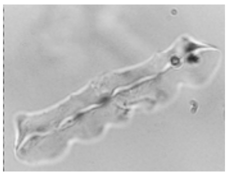
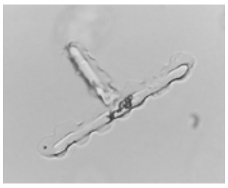
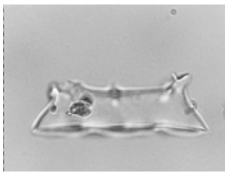
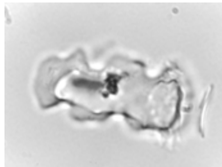
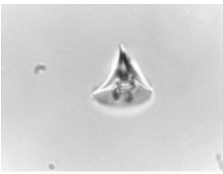
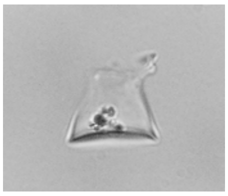
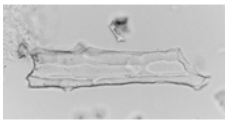
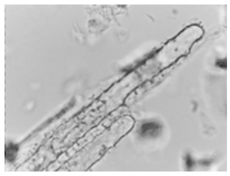
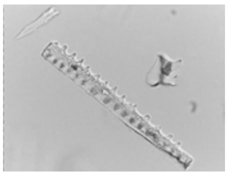
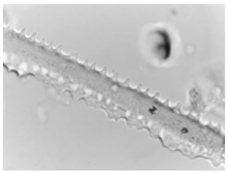
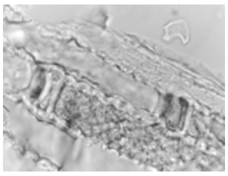
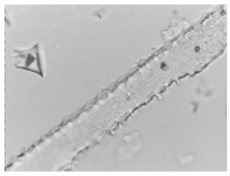
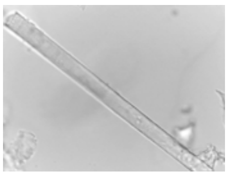
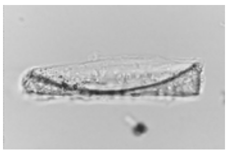
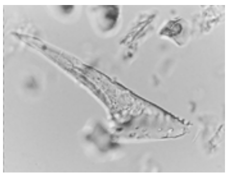
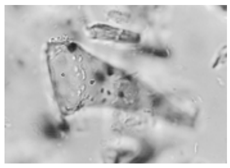
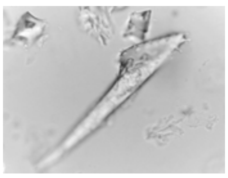
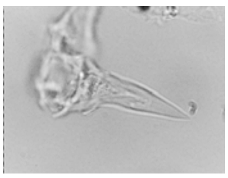
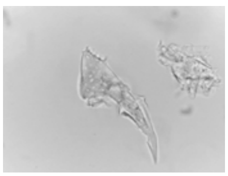
Grass



10 cm

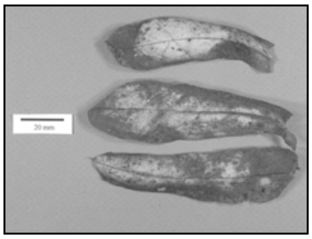
Plant origin: Campbell Island
Collected from: Campbell Island
Collected by: Carol West, Department of Conservation
Collection date: January 1995
Identified by: Carol West, Department of Conservation
Silica % of dried plant: 1.4

Morphotypes recognised: Polylobate, rondel, elongate, trichome

			
			
			
			
			Scale bars = 10 µm

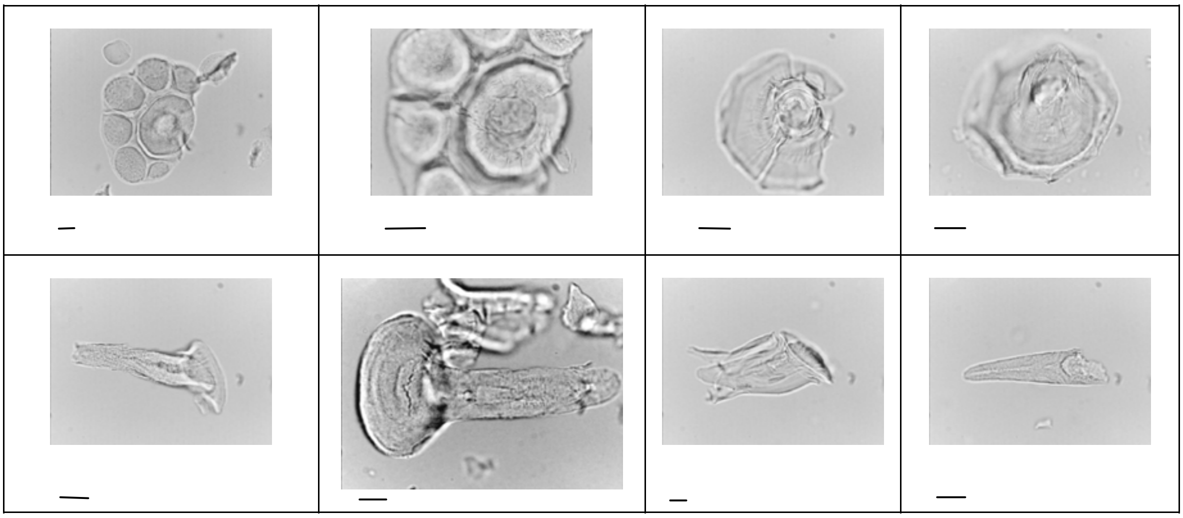
Boraginaceae *Myosotis capitata*

Tracheophyta, Angiospermophytina, Magnoliopsida, Lamiales Herb



Plant origin:	Auckland Island
Collected from:	Invercargill
Collected by:	Keith Dudfield, Invercargill City Council
Collection date:	July 2002
Identified by:	Keith Dudfield, Invercargill City Council
Silica % of dried plant:	0.5

Morphotypes recognised: Trichome, mesophyll

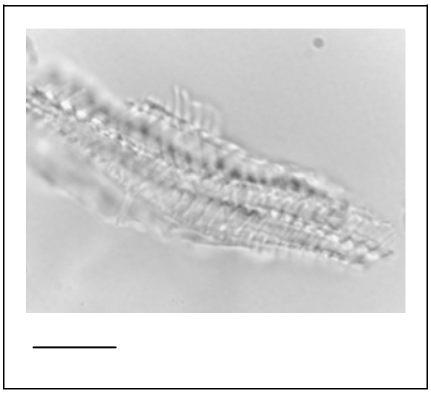


Scale bars = 20 μm

Asteraceae ***Anaphalioides bellioides***

Tracheophyta, Angiospermophytina, Magnoliopsida, Asterales Herb

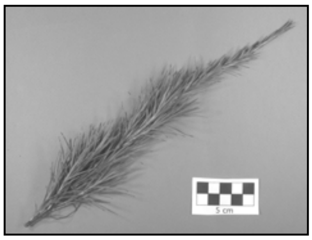
Plant origin:	Otari Botanic Gardens, Wellington
Collected from:	Otari Botanic Gardens, Wellington
Collected by:	Vanessa Thorn
Collection date:	February 2002
Identified by:	Eleanor Burton, Otari Botanic Gardens
Silica % of dried plant:	0.5
Morphotypes recognised:	Tracheid, mesophyll



Scale bar = 20 µm

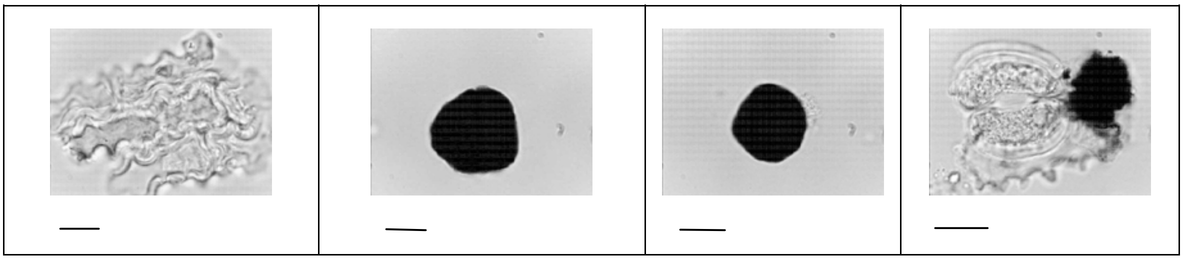
Epacridaceae *Dracophyllum scoparium*

Tracheophyta, Angiospermophytina, Magnoliopsida, Ericales Shrub



Plant origin: ?Auckland Island
Collected from: Queen's Park, Invercargill
Collected by: Keith Dudfield, Invercargill City Council
Collection date: July 2002
Identified by: Fanie Ventner, SBS, VUW
Silica % of dried plant: 0.04

Morphotypes recognised: Elongate, opaque spherical, stomata (?contaminant)

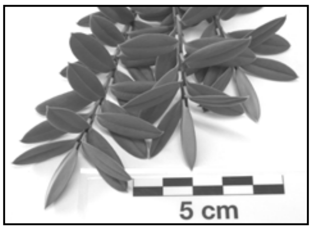


Scale bars = 10 μm

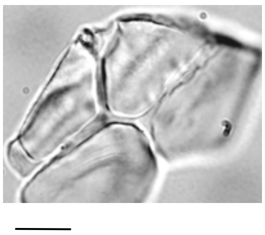
Scrophulariaceae *Hebe elliptica*

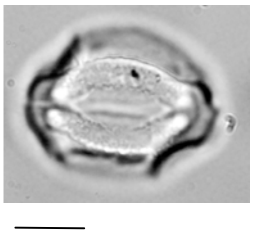
Tracheophyta, Angiospermophytina, Magnoliopsida, Scrophulariales

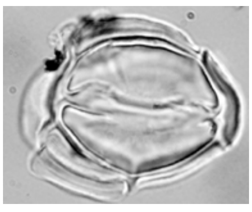
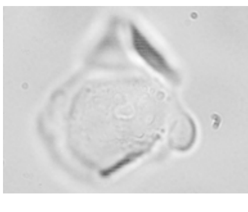
Shrub



Plant origin:	VUW
Collected from:	VUW
Collected by:	Vanessa Thorn
Collection date:	November 2002
Identified by:	Phil Garnock-Jones, SBS, VUW
Silica % of dried plant:	0.06
Morphotypes recognised:	Epidermal, stomata, tracheid





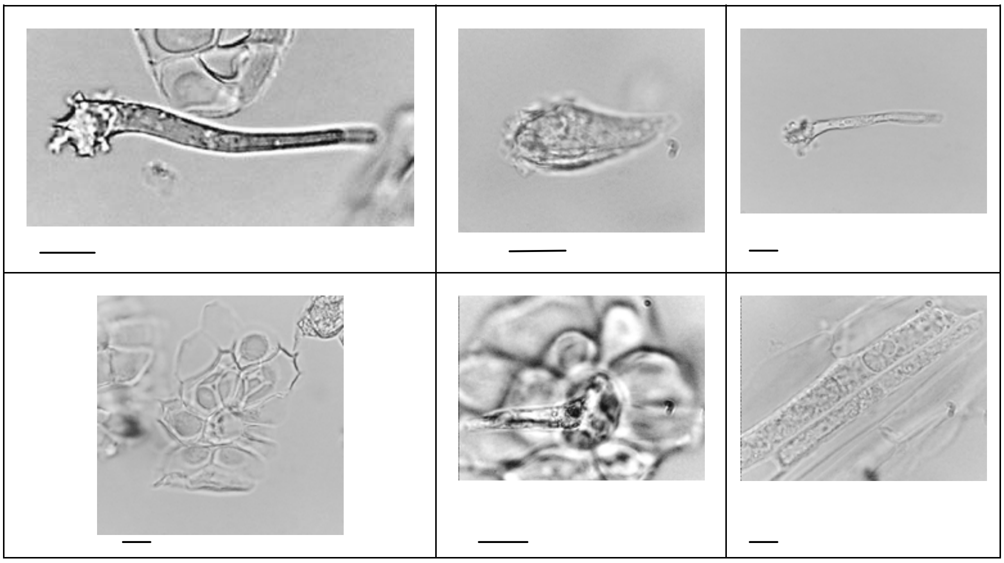
Scale bars = 10 μm

Rosaceae *Acaena anserinifolia*

Tracheophyta, Angiospermophytina, Magnoliopsida, Rosales — Herb

Plant origin:	Otari Botanic Gardens, Wellington
Collected from:	Otari Botanic Gardens, Wellington
Collected by:	Vanessa Thorn
Collection date:	February 2002
Identified by:	Eleanor Burton, Otari Botanic Gardens
Silica % of dried plant:	5.4

Morphotypes recognised: Trichome, epidermal, tracheid



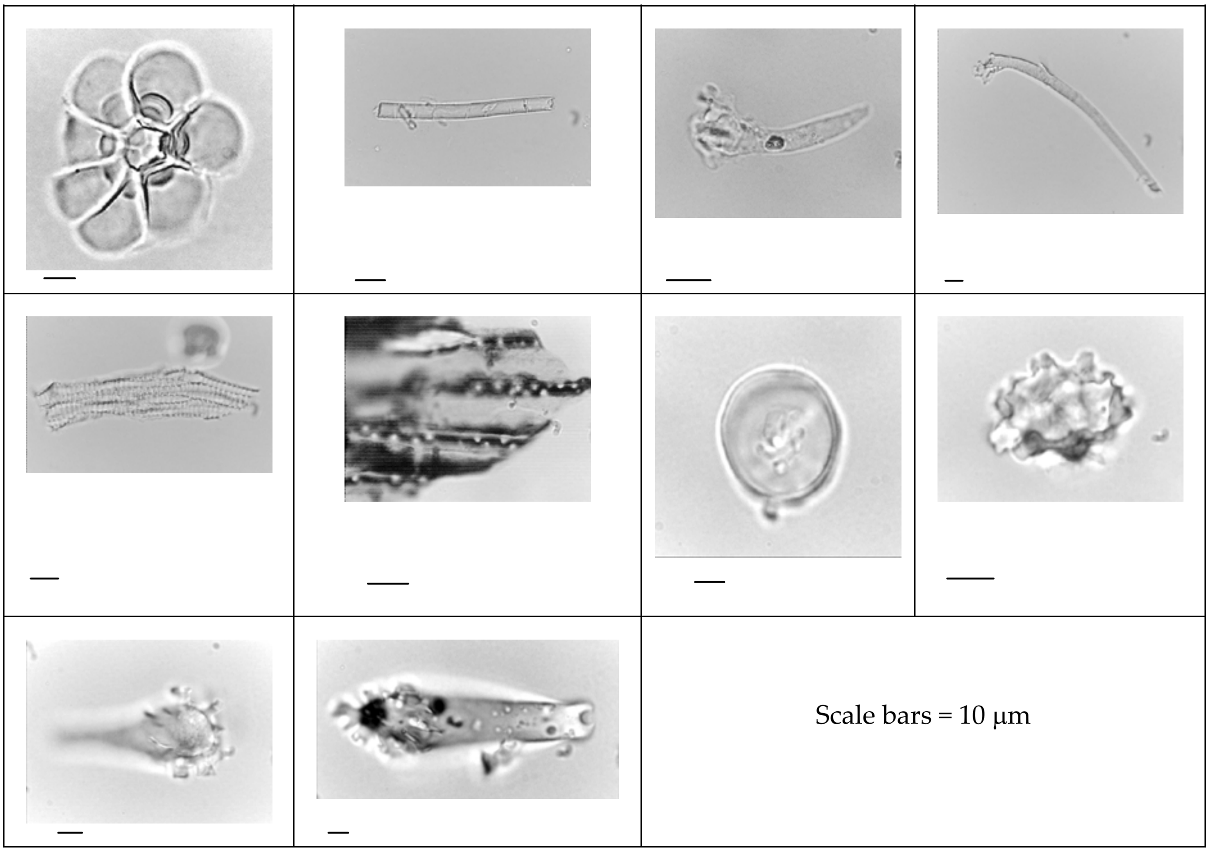
Scale bars = 10 μm

Rosaceae *Acaena minor* **var.** *antarctica*

Tracheophyta, Angiospermophytina, Magnoliopsida, Rosales Herb

Plant origin: Otari Botanic Gardens, Wellington
Collected from: Otari Botanic Gardens, Wellington
Collected by: Vanessa Thorn
Collection date: February 2002
Identified by: Eleanor Burton, Otari Botanic Gardens
Silica % of dried plant: Negligible

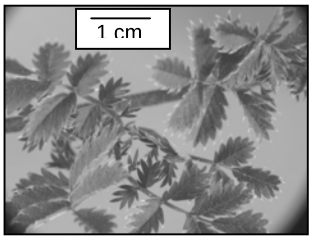
Morphotypes recognised: Trichome, tracheid



Scale bars = 10 μm

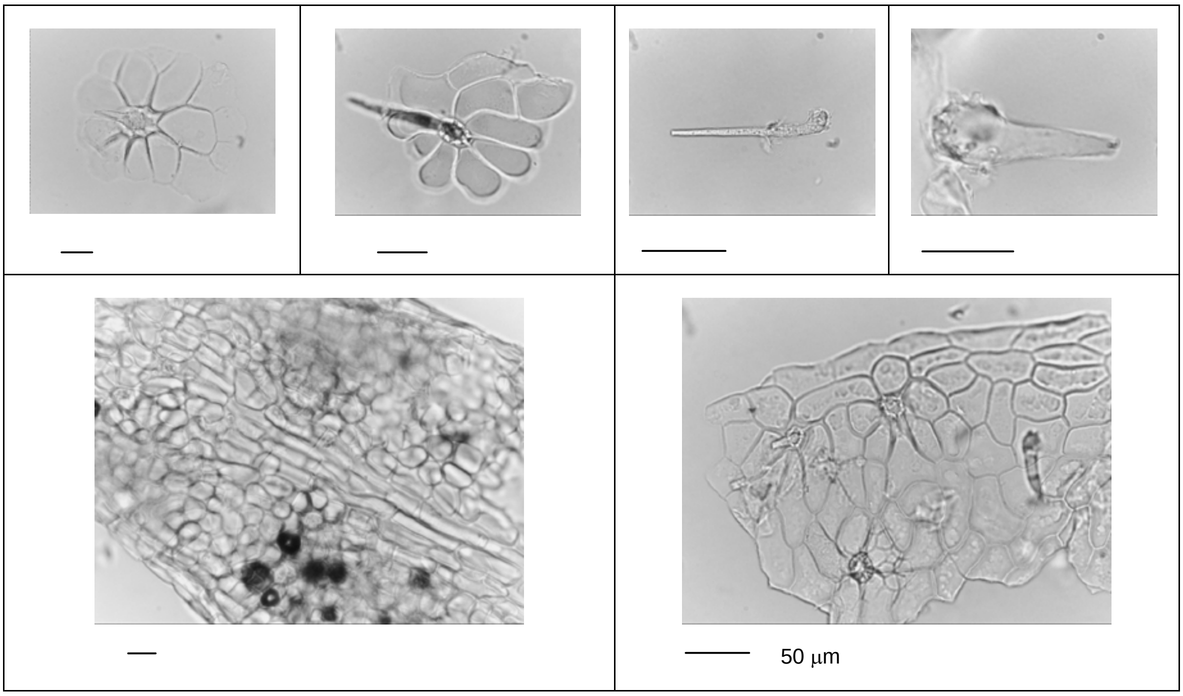
Rosaceae *Acaena novae-zelandiae*

Tracheophyta, Angiospermophytina, Magnoliopsida, Rosales Herb



Plant origin: Otari Botanic Gardens, Wellington
Collected from: Otari Botanic Gardens, Wellington
Collected by: Vanessa Thorn
Collection date: February 2002
Identified by: Eleanor Burton, Otari Botanic Gardens
Silica % of dried plant: 1.2

Morphotypes recognised: Trichome, elongate, mesophyll



All but bottom right scale bars = 20 µm

Acknowledgements

The research that this report partially represents was undertaken during the tenure of a 3 year New Zealand Science and Technology Post-Doctoral Fellowship funded wholly by the Foundation for Research, Science and Technology, between 2001 and 2004. The Antarctic Research Centre (under the direction of Professor Peter Barrett), the School of Earth Sciences and Victoria Link Limited at Victoria University of Wellington jointly hosted this Fellowship.

Particular thanks are due to the following people: Peter Barrett, Mike Hannah, John Carter, Phil Garnock-Jones (all at Victoria University of Wellington), Ian Raine (Institute of Geological and Nuclear Sciences, Lower Hutt), Rosie Askin (formerly at the Byrd Polar Research Centre, Ohio State University), Eleanor Burton (Otari Botanic Gardens, Wellington), Keith Dudfield (Invercargill City Council), Carol West (Department of Conservation), John Smellie (British Antarctic Survey) and Doreen Bowdery (Australian National University, Canberra).

Index